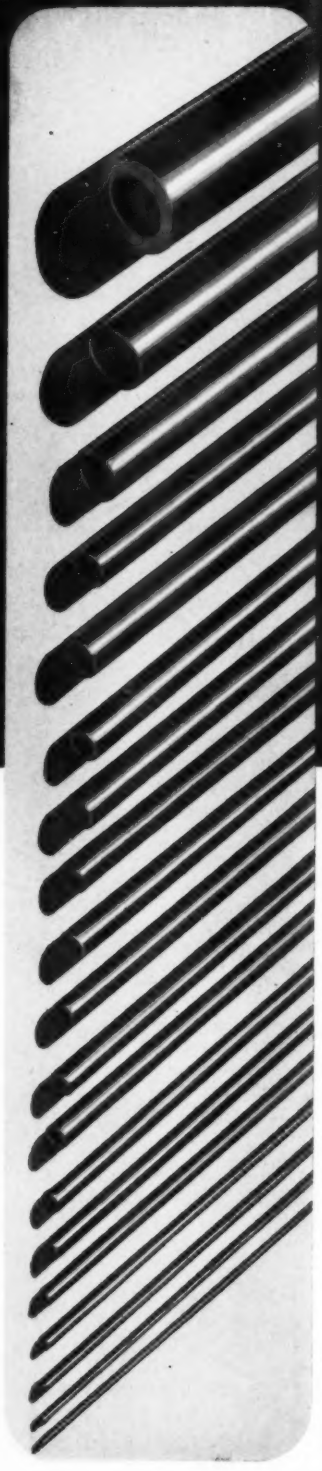
July 1943

TECHNOLOGY REVIEW

Title Reg. in U. S. Pat. Office



Strong, Pliable, with Excellent Electrical Characteristics

Sandee

FLEXIBLE PLASTIC TUBING

THE demand for this VERSATILE Plastic Tubing has grown tremendously with the scarcity of rubber, tin, aluminum and other crital materials. Electrical War Industries have found many applications where SANDEE Flexible Tubing has proved more efficient than materials previously used! This remarkable product has *excellent electrical characteristics*, and is highly resistant to oils, acids, greases. It possesses ample tensile strength which can be further increased with woven fabric covering. Sandee Flexible Tubing is precision-made of transparent or opaque materials, in different colors, dull or glossy finish. It is custom made in various degrees of thickness and flexibility, in many sizes and lengths. This tubing serves efficiently for wire and cable insulation, antenna and transformer leads, cable end sleeves, grommets, cushions, battery drains, oil lines, air hosing, and wherever a tough, protective covering is required. SANDEE Extruded Thermoplastics are also formed into many different stock and custom sections to exacting specifications. Write today for samples, catalog sheet, and complete information.

ELMER SZANTAY, M.E. '35, *GENERAL MANAGER*

Sandee Manufacturing Company

3945 NORTH WESTERN AVENUE • CHICAGO, ILLINOIS

EXTRUDED PLASTICS AND SPECIAL TOOLS

Your Workers, Your Company, Your Country

All Lose—*with "Lost-Time Eyes"*

. . . protect workers' eyes with AO Goggles

What does a worker think about while lying in a hospital bed or at home, suffering from an injured eye? He thinks of his own pain . . . the worry of his family . . . his lost time. He builds up a resentment against his company for not providing him with the proper eye protection.

But an eye-injured worker is not the *only* loser. Companies that *allow* "lost-time eyes" to happen also lose heavily in hard-earned dollars, irreplaceable workers, invaluable production. And as a result, our Country . . . for which we are all fighting . . . loses heavily, too, in vital war equipment.

Give your men and women workers AO Goggles to give our fighting forces *what they must have for Victory*. AO Goggles are strong and sturdy . . . yet they are also light and comfortable. Equipped with Super Armorplate Lenses, they provide maximum protection against impact. Have your Safety Director get in touch with the nearest American Optical office.

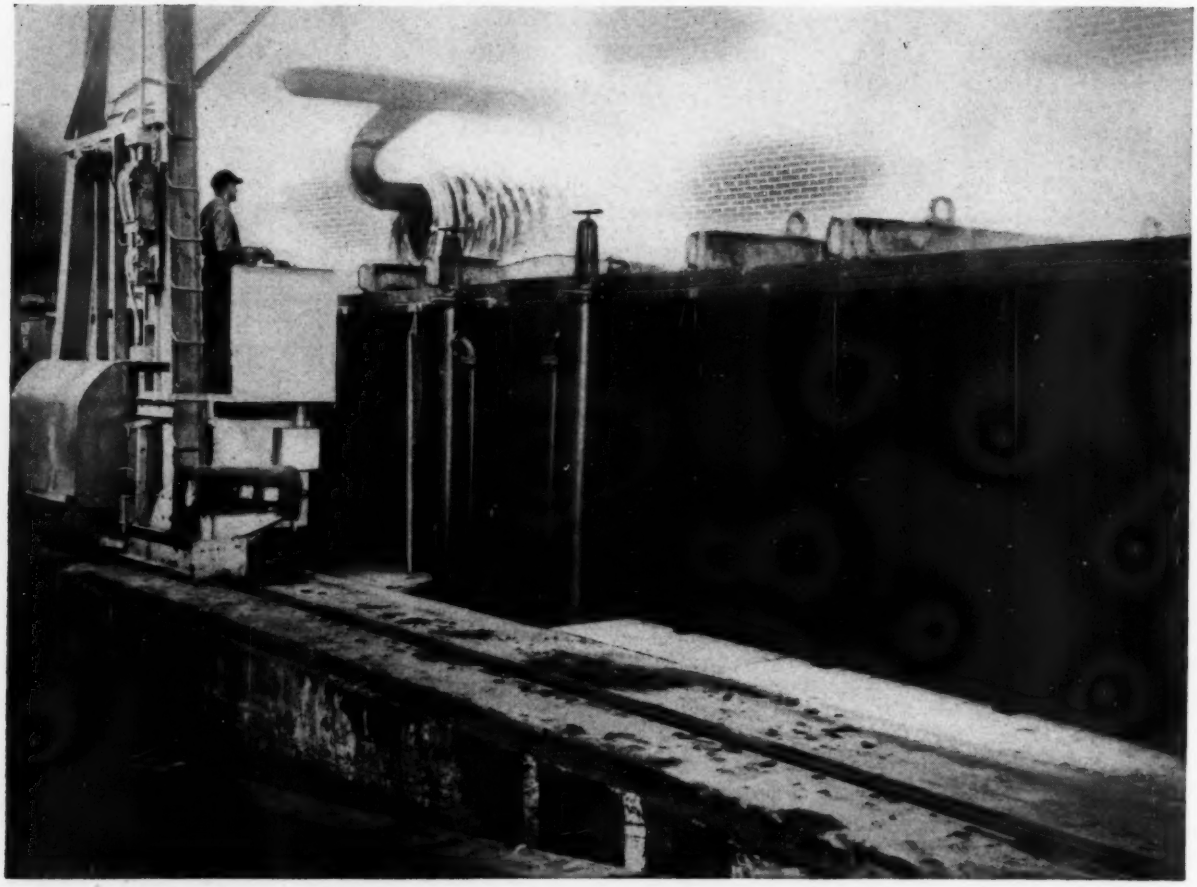
American Optical

COMPANY

SOUTHBRIDGE, MASSACHUSETTS

MANUFACTURERS FOR 110 YEARS OF PRODUCTS TO AID AND PROTECT VISION. BRANCHES IN ALL PRINCIPAL INDUSTRIAL CENTERS

THE TECHNOLOGY REVIEW, July, 1943. Vol. XLV, No. 9. Published monthly from November to July inclusive at 10 Ferry Street, Concord, N. H. Publication date: twenty-seventh of the month preceding date of issue. Annual subscription $3.50; Canadian and Foreign subscription $4.00. Entered as second-class matter at the Post Office at Concord, N. H., under the Act of March 3, 1879.



EVEN HOT SULPHURIC ACID CAN'T DULL THE GLOSS OF TYGON PAINT!

PAINT seldom faces a tougher job than when used on the exterior of hot, non-ventilated pickling tanks. In addition to the viciousness of the fumes arising from hot sulphuric acid, there is the frequent spillage that occurs, plus the moisture which aggravates any corrosive condition.

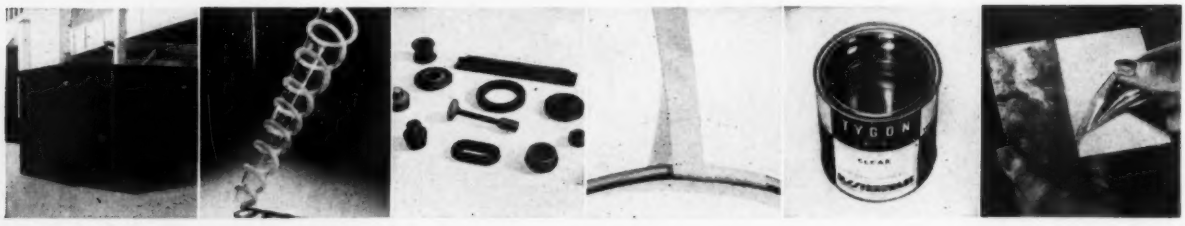
In this toughest kind of service, where the life of most industrial paints is measured in terms of but a few months (sometimes but a few weeks) Tygon Paint is still taking it, the original gloss not even dulled after more than fifteen months!

The reason? Tygon Paint is, essentially, pure Tygon (the chemically inert, rubber-like plastic used to line tanks in which corrosives are made and handled) liquefied by the addition of appropriate solvents. These solvents, on evaporation, leave a sturdy, durable film of chemically unchanged Tygon.

Tygon Paint films are odorless when dry, tasteless, and relatively non-toxic (they may be formulated to be totally non-toxic, if desired). The films are tough, flexible, and non-inflammable. Tygon Paints show no tendency to crack, craze, check or "weather" even after long exposure to air, sunlight, moisture or other oxidizing elements. They are highly resistant to acids, alkalies, alcohols, greases, oils and fats. Certain formulations will even withstand hot aromatic fuels.

For detailed information on the use of Tygon Paints, and other Tygon corrosion-resistant materials: linings, rigid or flexible tubing, gasketing materials, impregnating solutions, or molded Tygon products, write: U. S. Stoneware Company, Akron, Ohio. In Canada: Chamberlain Engineering, Ltd., Montreal, Que.

U. S. STONEWARE
AKRON, OHIO



Give him the RIGHT GRINDING WHEEL

then let the Grindlins heckle

Yes, he's got to have a good weapon in the shop, too.

This combination for example—grinding steel castings, with high speed equipment, a rough and tough sort of a job, calls for a grinding wheel built for heavy duty and high speed.

You'd order for this job a Norton Resinoid bonded wheel, Alundum abrasive; and if without experience with this kind of work, you'd consult a Norton engineer, or a Norton distributor for more specific recommendations.

There is a Norton grinding wheel for every type of grinding. Your shop army must have the right equipment

NORTON COMPANY • Worcester, Massachusetts

Behr-Manning, Troy, N. Y. is a Norton Division

NORTON ABRASIVES

IRC RESISTORS Send the Signal

When trouble develops on a high voltage power line, time is of greatest essence. For in our fast-moving electro-mechanical age, minutes quickly translate themselves into countless man-hours. Communications go "dead" . . . lights snuff out . . . vital production grinds to a sudden halt . . . and it's "taps" for a busy world.

Another IRC Contribution

Until comparatively few years ago, when power transmission interruptions occurred, it often required hours to locate the trouble. Today, thanks in part to the contribution of I R C research engineers, the point of disruption in any electrical circuit—whether power or communications—can readily be spotted in a matter of moments.

Specially designed, IRC high voltage power resistors dependably dissipate the heavy loads and deliver the voltage required to operate trouble-signalling mechanisms. On receipt of signal, other instruments in which resistors play an important role accurately locate the point of disturbance within a few feet.

Here at I R C we welcome—and usually solve—unusual problems in the field of resistance devices. And because I R C makes more types of resistance units, in more shapes, for more applications than any other manufacturer in the world, many leading engineers make it a point to seek our unbiased counsel. There is no obligation, of course.

PREFERRED FOR PERFORMANCE
IRC
FIXED & VARIABLE RESISTORS

INTERNATIONAL RESISTANCE COMPANY

423 N. BROAD STREET · PHILADELPHIA

PENFLEX WELD

Corrugated Flexible All-Metal Tubing for Safety and Service on High Pressure Lines that MUST be Leak-proof

Flexibility combined with safety against all normal hazards; resistance to radial and longitudinal strains under high pressure; jointless, welded, leak-proof construction in lengths as needed—all these make PENFLEX WELD Tubing invaluable in handling volatiles, liquids and gases with penetrative or solvent characteristics.

PENFLEX WELD corrugation serves a two-fold purpose—*gives flexibility and develops high resistance to bursting, crushing, cracking or splitting.*

Also available to maintain the leak-proof service and flexibility of PENFLEX WELD are Solseal and Metseal Couplings. Solseal, for general use, designed for service where temperatures do not exceed 250° F. . . . Metseal, a positive metal-to-metal joint, provides tight joints for higher temperature—no packing used, metal must break or melt before joint will separate.

PENFLEX WELD Corrugated Flexible All-Metal Tubing, Solseal and Metseal Couplings are described in Bulletin 90. Write for it.

Flexible PENFLEX WELD Tubing—in sizes 5/32" to 2" I.D. . . . Bronze or Steel Construction.

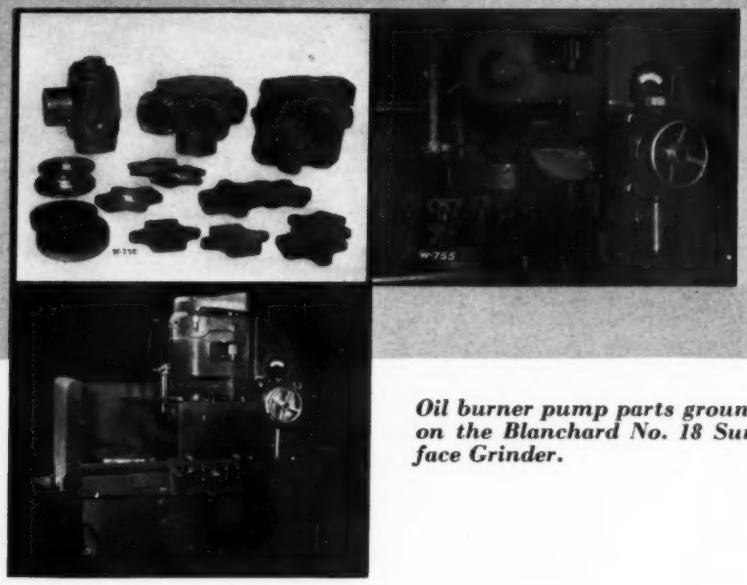
PENFLEX METAL HOSE

PENNSYLVANIA FLEXIBLE METALLIC TUBING CO.

7227 Powers Lane, Philadelphia, Pa.

ESTABLISHED 1902

CHECK THESE ADVANTAGES OF BLANCHARD GRINDING



Oil burner pump parts ground on the Blanchard No. 18 Surface Grinder.

- ★ **Production**
- ★ **Adaptability**
- **Fixture Saving**
- **Operation Saving**
- **Material Saving**
- ★ **Fine Finish**
- ★ **Flatness**
- ★ **Close Limits**

THE BLANCHARD NO. 18 SURFACE GRINDER is used to rough and finish grind the oil burner pump parts shown above. They are first ground from the rough, then they are normalized and ground again. All boring and drilling operations are located from the flat Blanchard ground surfaces. After machining, all parts are finish ground on the Blanchard. Twelve pump bodies are ground at once on fixtures mounted on one base plate. The base plate is held magnetically, therefore the chuck may be cleared quickly for a change of jobs. The cast iron pump bodies are 6 inches in diameter. .012″ of stock is ground off one side to limits of +.0003″ —.0001″ at a rate of 48 pieces per hour.

★ . . . . . *Especially valuable on jobs like the one illustrated.*

The **BLANCHARD MACHINE COMPANY**

64 STATE STREET, CAMBRIDGE, MASS.

BLANCHARD

Send for your free copy of "Work Done on the Blanchard." This book shows over 100 actual jobs where the Blanchard Principle is earning profits for Blanchard owners.

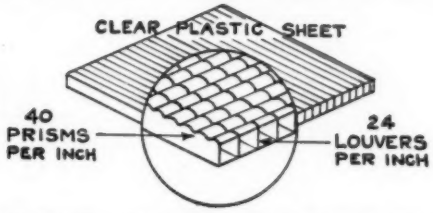
TO *Stop Glare* USE

"LOUVERPLAS"

Reg. Trade Mark

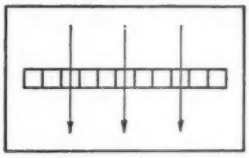
THE LOUVERED PLASTIC SHEET • CONTROL FLUORESCENT LIGHTING TO IMPROVE YOUR SEEING EFFICIENCY

NON-FRAGILE CELLULOSE ACETATE

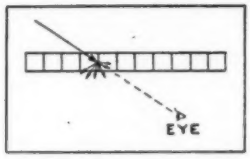


USED BY THE ARMY AND NAVY

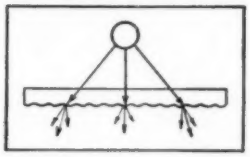
"LOUVERPLAS" GLARE ZONE SHIELDING



Sheet is composed of clear plastic alternately spaced with thin white translucent or black opaque plastic louvers. The clear plastic has high transparency for light transmission. Light is efficiently directed to the work area where it is required, not into the eyes.



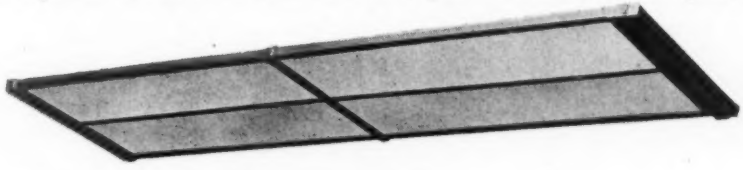
Louvers are the most effective method for the lengthwise control of the fluorescent lamp. As used in the Glare Zone Shield, the thin white translucent louvers diffuse the light within the glare zone that would otherwise enter the eyes as glare. Black opaque louvers will completely obscure the light source from vision. The degree of light control can be varied by the thickness of the sheet.



Prisms are applied to the surface of Louverplas perpendicular to the louvers. The prisms disperse the light source image and control the light in directions parallel with the clear plastic, lowering the surface brightness and eliminating glare. As used in the Glare Zone Shield, the prisms give efficient sidewise control.

Louverplas Glare Zone Covers for Industrial Reflectors

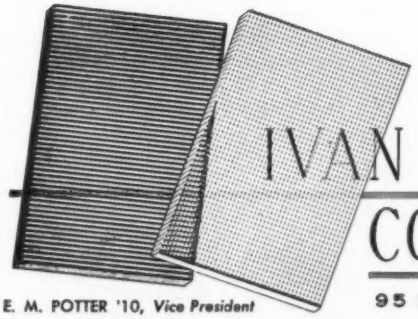
STOP EYE FATIGUE



SPEED UP PRODUCTION

Recommended Louverplas Uses

- **WHITE** — "Glare Zone Covers" for fluorescent lighting fixtures, industrial reflectors and marine fixtures.
- **BLACK** — "Vision Expediting" covers for industrial fluorescent reflectors, for close tolerance manufacturing and inspection of war materials.
- **BLACK** — "Louvered Shields" for Cathode-ray Tube devices improving visibility of sine wave.
- **BLACK or WHITE** — Many other industrial or scientific uses for light control.

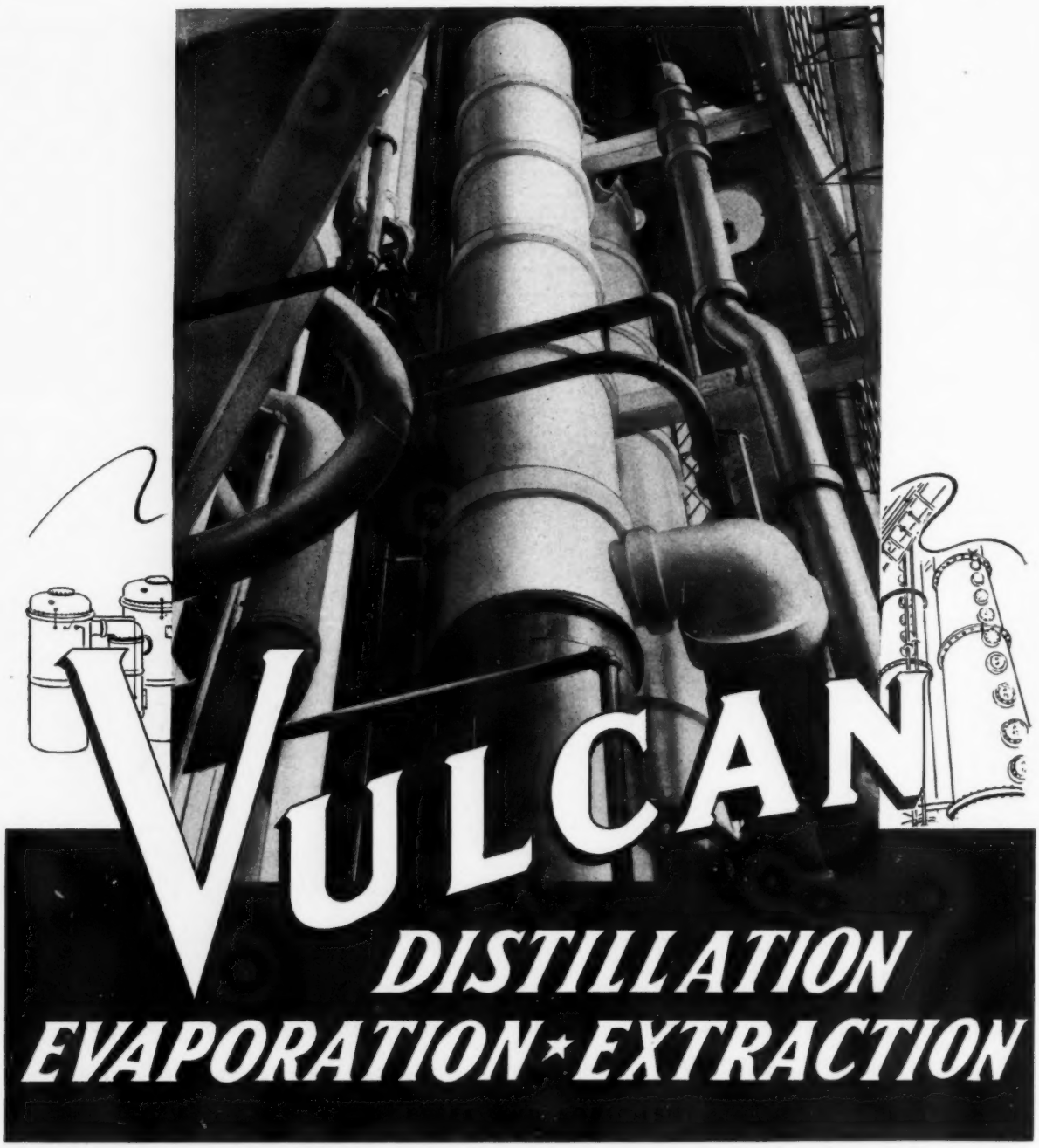


IVAN T. JOHNSON COMPANY, INC.

E. M. POTTER '10, *Vice President*

95 MADISON AVE., NEW YORK

National Distributors for THE DOANE PRODUCTS CORPORATION, MERIDEN, CONNECTICUT



VULCAN

DISTILLATION
EVAPORATION ★ EXTRACTION

THE demands placed upon chemical engineering organizations by the National Emergency are far reaching and extend into many industries. The Vulcan organization has made many important contributions to the expansion of the process industries during the past 41 years. This fact has made the wartime conversion of these industries a much easier task than would otherwise have been possible without the progressive developments offered by the Vulcan organization in the fields of Distillation, Evaporation and Extraction. Vulcan is proud of the important part which its contribution to chemical engineering is playing in American industry today.

VULCAN COPPER AND SUPPLY CO.
CINCINNATI, O., U.S.A.

Enemies Unseen . . . but for the Microscope

Bausch & Lomb microscopes, on every battlefront and at home, are helping to keep America's workers and America's fighters healthy . . . are helping to free them from the menace of invisible enemies.

Into a world otherwise invisible men with microscopes seek out the enemy that hides in the water, the soil and the air . . . help to keep fighting men in fighting trim. At home, their work protects America's industrial army which must, without fail, provide fighting tools for our fighting men.

Bausch & Lomb development of a mass production technique for the manufacture of precision optical instruments first made high quality microscopes available to all.

This same experience today is making possible the mass production of optical fire control instruments that help to make America's fighting forces the best equipped in the world.

For Bausch & Lomb Instruments essential to Victory—priorities govern delivery schedules.

BAUSCH & LOMB

OPTICAL CO. • ROCHESTER, NEW YORK
ESTABLISHED 1853

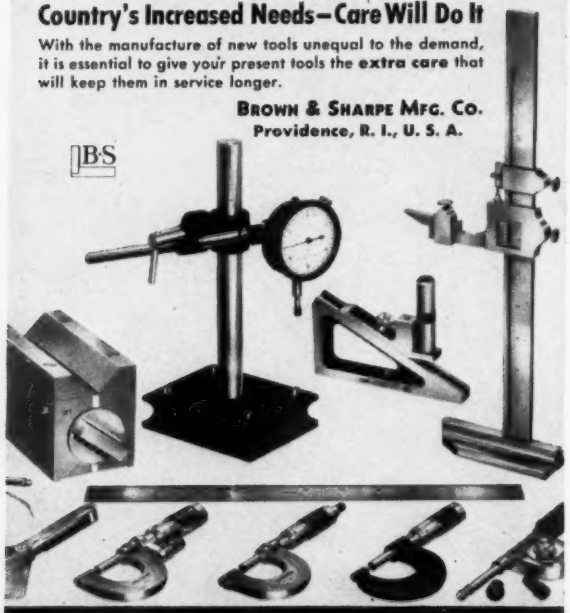
AN AMERICAN SCIENTIFIC INSTITUTION PRODUCING OPTICAL GLASS AND INSTRUMENTS FOR MILITARY USE, EDUCATION, RESEARCH, INDUSTRY AND EYESIGHT CORRECTION

Help Extend Tool Life to Meet Your Country's Increased Needs—Care Will Do It

With the manufacture of new tools unequal to the demand, it is essential to give your present tools the **extra care** that will keep them in service longer.

BROWN & SHARPE MFG. CO.
Providence, R. I., U. S. A.

B·S



BROWN & SHARPE TOOLS

BATH
IRON WORKS
CORPORATION

Shipbuilders and Engineers

•

BATH, MAINE

THE TABULAR VIEW

Figures. — Mars as mathematician and the effect of his requirements on American higher education are surveyed on page 481 by GEORGE W. GRAY, well known to Review readers as a keen thinker and interesting writer on matters scientific. Mr. Gray's article is drawn from a chapter of his book, *Science at War*, which Harper will publish in the fall.

Arches. — From his own primary field of anatomy, M. F. ASHLEY MONTAGU of the Hahnemann Medical College and Hospital of Philadelphia brings forward (page 483) an example of natural architecture and mechanics which is of direct personal interest to human beings. His description of the ingenious construction of the human skull presents nature as an extremely skillful builder.

Exhibits. — Chairman of the Committee on the Technology Museum, ARTHUR C. WATSON demonstrates regularly through ingenious display of interesting materials in the corridors and museum areas of the Institute the practical worth of his theory of museum work stated on page 487.

Adventures. — Elihu Thomson, scholar, inventor, teacher, who from 1894 to 1937 was a member of the Institute's Department of Electrical Engineering and was twice acting president of the school between 1920 and 1923, encountered a blessing in disguise during his early education. How he used it is told (page 489) by DAVID O. WOODBURY, '21, in an article based on a chapter from his biography of the scientist, publication of which in the fall is scheduled by Whittlesey House. Author of varied volumes on topics from science and engineering, Mr. Woodbury conducts in *Collier's* a weekly department, "Your Life Tomorrow," which surveys contemporary developments in these fields.

Adaptations. — How workers in science and engineering constitute a control group in the population and must adapt to other similar groups was the theme stressed in a penetrating commencement address (page 491) to recipients of degrees from the Institute this spring, by JOHN W. M. BUNKER, Dean of the Graduate School at Technology.

Anniversary. — HEWITT G. FLETCHER, JR., '39, instructor in chemistry at Technology, is an enthusiastic student of the history of his subject and particularly of Antoine Laurent Lavoisier, whose bicentenary he discusses on page 478.

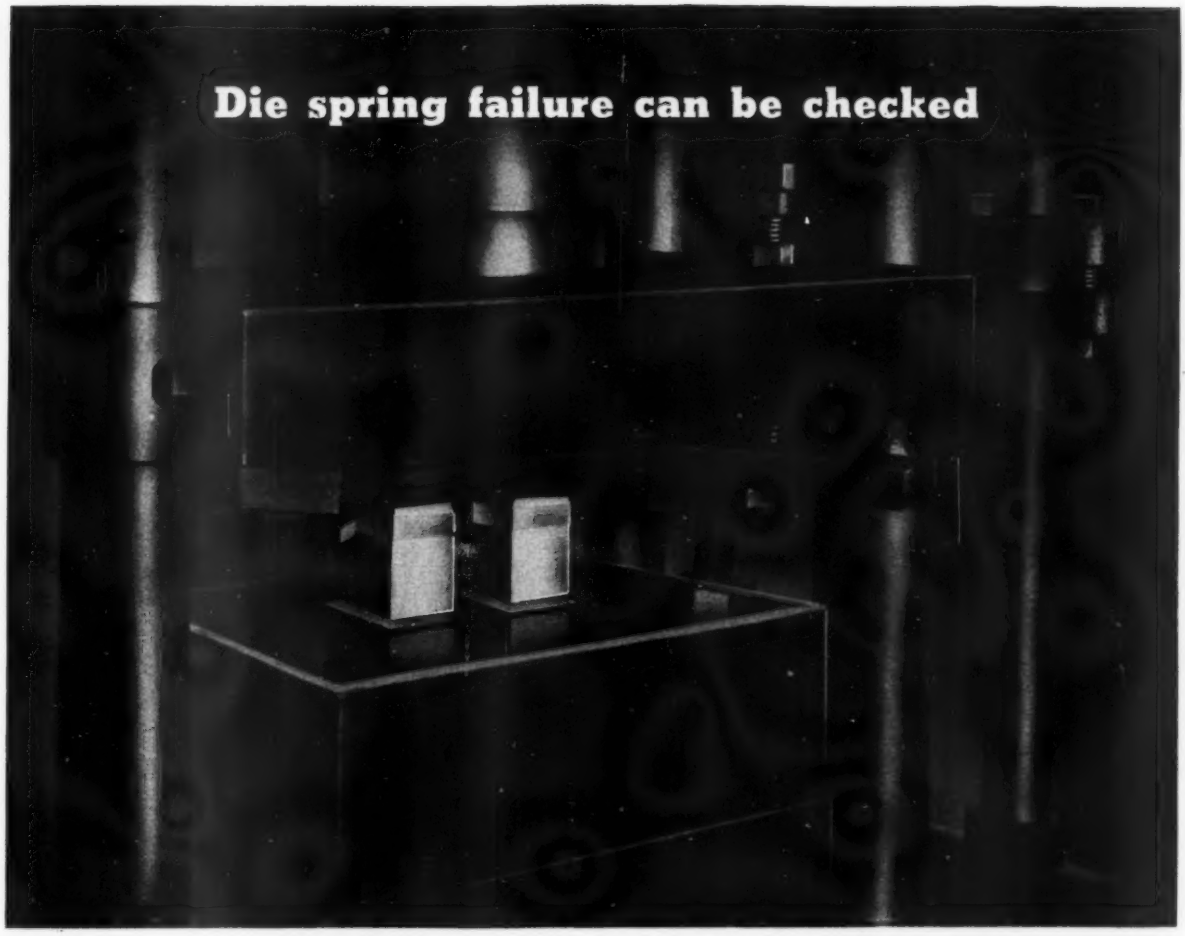
Speed with Economy

Chas. Pfizer & Co., Inc.

The broad experience we are gaining in wartime construction and the methods we have developed to overcome difficulties, will prove extremely valuable to industry after the Victory is won.

W. J. BARNEY CORPORATION
101 PARK AVENUE, NEW YORK
INDUSTRIAL CONSTRUCTION
Alfred T. Glassett, '20, Vice President

Die spring failure can be checked



Information supplied by an Industrial Publication

A recent investigation of die spring breakage developed the following prominent causes:

1. Hydrogen embrittlement resulting from plating, pickling or cleaning.
2. Incorrect die design.
3. Incorrect spring size.
4. Speed of compression cycle.
5. Poor quality of wire.

There are, fortunately, remedies for all these conditions. Hydrogen embrittlement can be corrected by heating plated springs to about 450°F. and air cooling.

Faults in die design usually consist of either insufficient or too great clearance between the outside diameter of the spring and the guide hole. The clearance should be such that the spring operates freely, but has no chance to buckle.

Care should be taken in selecting springs to see that they are properly designed for both length of compression stroke and speed of compression. If springs are repeatedly compressed too close to their solid height, quick failure will result. The same is true where the rapidity of compression is too great.

It seems obvious that the quality of the spring wire should be commensurate with the job. Cheap wire should be avoided because of defects that are bound to cause trouble, especially when springs are plated.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

ARMY E NAVY

MOLYBDIC OXIDE, BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

Climax Molybdenum Company

500 Fifth Avenue • New York City

MOLY

FOR *Victory* AND AFTER

★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Our research to maintain and improve the quality of Simplex insulated wires and cables, under restrictions designed to save critical materials, is getting results that mean better insulated conductors for commercial use after the war.

Simplex Wire & Cable Co.
79 Sidney Street, Cambridge, Mass.

Reg. U. S. Pat. Off.

Samson Cordage Works

Boston, Mass.

Herbert G. Pratt, '85, *Chairman of the Board*

Manufacturers of braided cords of all kinds, including sash cord, clothes line, trolley cord, signal cord, shade cord, Venetian blind cord, awning line, etc., also polished cotton twines, ladder tape for Venetian blinds, and specialties.

SAMSON SPOT CORD

Reg. U. S. Pat. Off.

Our extra quality sash cord, distinguished at a glance by our trade-mark, the colored spots. Especially well known as the most durable material for hanging windows, for which use it has been specified by architects for nearly half a century.

MAIL RETURNS

Fred Allen Remarks

For his sapient radio commentary on life, for his being a prominent alumnus of electronics, and for his once having skillfully presided at an M.I.T. alumni gathering, The Review has looked to the day when Fred Allen might write for it what he thinks about science, and so on. The letter which follows is a guidepost on that literary journey. — *Ed.*

DEAR MR. FASSETT, JR.

i haven't had time to answer your * until today. i am incessantly having to put off until tomorrow things that should be done today. (the word missing * is epistle.) i have been putting off this answer until tomorrow until today. in order to find time to permit me to beat out this document i had to reroutine my putting off until tomorrow practice. yesterday, the thing i was going to put off until tomorrow, which would have been today, i put off until the day after tomorrow. what i intended to put off today i put off until yesterday. that gave me today free to answer some mail. you can see how involved one gets when one has spent 11 years in radio.

the saturday evening post piece did mention that i would like to write. i would enjoy writing. my problem is that i have been so busy writing that i haven't had time to learn how to write. i am strictly a conjunction man. "if" i had time "and" could read "or" study i would attempt to write. "since" pantalooning keeps me too busy it doesn't look "as" "though" i shall ever get my "but" in a chair long enough to learn the rudiments of scrivening.

i remember the m.i.t. alumni gathering at mechanics building. i replaced doctor rockwell as compere on that occasion. rockwell had his thumb caught in a clam up at boothbay harbor. with his preaxial digit trapped rockwell was in no position to hitchhike down to boston. i doubt that deputizing for rockwell at that gala affair entitles me to regard myself as an alumnus of m.i.t. i took a summer course at boston university and my name is never mentioned about the b.u. corridors.

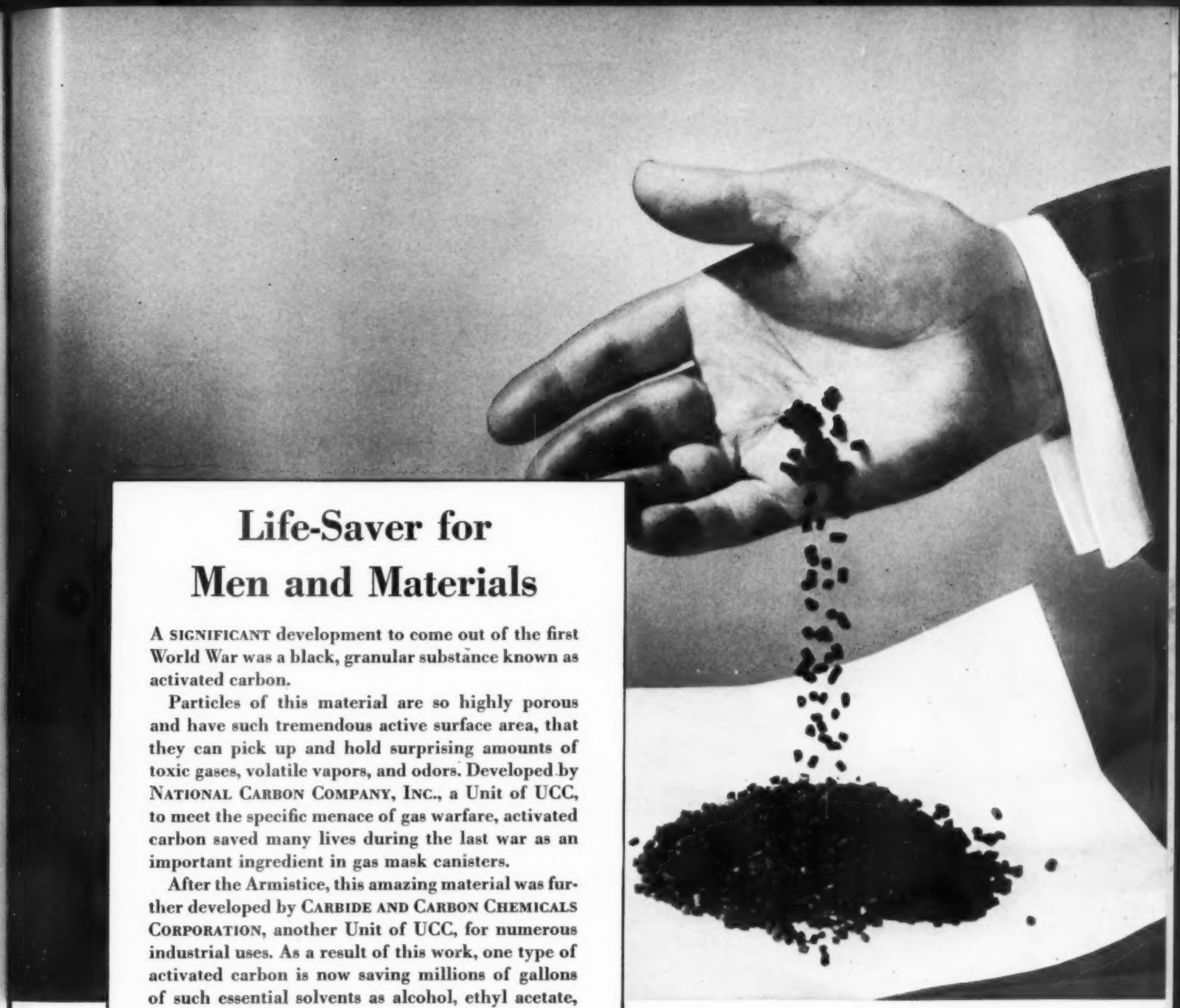
the man who invented the tube which takes advantage of the gregarious habits of electrons did me no favor. in vaudeville, my blood pressure was low, i had time to spend on correspondence or with friends, i carried some good books in my trunk and had time to read them between shows and on trains. i was leading the life of the well-known riley and didn't know it. today, as you say, i have been skyrocketed to reverse obscurity. i have essential hypertension, no time to myself, and fifty pages of dialogue to grind out every week. success, mr. fassett, is a status one person enjoys in the estimation of another person. i would rather be a buxom failure than a neurotic success. most success today is nothing but a short cut to an ulcer.

you say that i can turn my wit and satire loose on 100,000,000 a week. the top-ranking show in radio, according to the surveys, draws but thirty-odd million listeners each week. i am not the top-ranking show. my wit and satire cannot even be turned on the people who listen to me. when a comedian has written a script and has eliminated the subjects blue-penciled by the network censor, when he has made further deletions to please the sponsor, who has his own policy rulings, when he has omitted other matter to pacify the advertising agency handling the program, when he has had to ask permission to mention singing sam and finds that he cannot get permission and the joke finally turns out to be about dick tracy, when he has had to add some obvious lines to get a reaction from the studio audience so that laughter will go out over the air to prove that the comedian's material is funny, when all of these and other modifications and ramifications have been coped with each week, the radio comedian finds that he isn't shaping the thinking of millions of people. millions of people are shaping his thinking.

this will give you an uncouth idea of what the man who invented the tube which takes advantage of the gregarious habits of electrons has done for me. still you are not satisfied, mr. fassett, you want me to write something for the technology review. i know! you've got some rejection slips left over. you are trying to lead me on.

if i had an idea for a piece i haven't strength enough to kick it around.
hoping this finds you the same, etc,
i am
you are
he is.....

FRED ALLEN



Life-Saver for Men and Materials

A SIGNIFICANT development to come out of the first World War was a black, granular substance known as activated carbon.

Particles of this material are so highly porous and have such tremendous active surface area, that they can pick up and hold surprising amounts of toxic gases, volatile vapors, and odors. Developed by NATIONAL CARBON COMPANY, INC., a Unit of UCC, to meet the specific menace of gas warfare, activated carbon saved many lives during the last war as an important ingredient in gas mask canisters.

After the Armistice, this amazing material was further developed by CARBIDE AND CARBON CHEMICALS CORPORATION, another Unit of UCC, for numerous industrial uses. As a result of this work, one type of activated carbon is now saving millions of gallons of such essential solvents as alcohol, ethyl acetate, ether, and acetone, previously lost through evaporation in manufacturing processes. This is accomplished by passing vapor-laden air from solvent-using processes through tanks containing COLUMBIA activated carbon, and then steaming the solvents out of the carbon.

This year, in smokeless powder plants, plants making plastics, and in other plants engaged in war work, it is estimated that savings will amount to over 100 million gallons of solvents.

And the work of activated carbon is just beginning. Through the constant research that typifies all UCC Units, CARBIDE AND CARBON CHEMICALS CORPORATION has developed still newer uses which are contributing to the nation's health and welfare.

BUY UNITED STATES WAR BONDS AND STAMPS

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VOLUME 45 NUMBER 9

THE TECHNOLOGY REVIEW

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AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Partridge from Black Star

A saw for Gargantua is this one slicing its way through armor plate in a naval ordnance plant.

THE
TECHNOLOGY
REVIEW

Vol. 45, No. 9 July, 1943

The Trend of Affairs

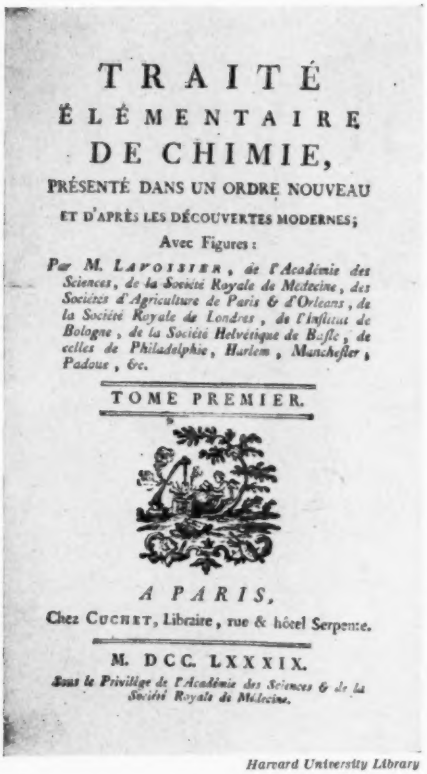
The Open Sky

A PROGRAM destined to give Pan American Airways 50 giant Clippers, each able to take scores of passengers from New York to London in 10 hours at a fare of $100, is already under way, says Juan T. Trippe, President of Pan American. In the light of accomplishments by air transport in this war and of technical advances on the horizon, nothing in this little glimpse of postwar aviation is unbelievable or even startling. What is probably worrying all air lines, here and abroad, which have international aspirations is not planes or passengers but whether permission can be obtained to fly a given route and land at a destination on foreign soil.

Unlike the sea, the skies have not yet been declared free or, in the British phrase, open. A shipping line can plan a route with confidence that it can enter and trade in any port it puts on its itinerary, except for certain regulations affecting all foreigners equally (only American ships, for example, can engage in coastal shipping along the United States). Instead of negotiating or intriguing with its own or other governments, a shipping line can devote most of its attention to the technical or economic problems associated with the route. Not that this situation was always so. When the great Portuguese explorers opened the sea route to India, they considered that the waters they traversed were as much the sovereign territory of their king as were the lands they found, and it took centuries for that concept to evaporate completely. To a large degree, the international law relating to air traffic would seem to be in as primitive a state as was sea law in the Seventeenth Century.

The reason is not hard to see. Nations have suddenly discovered that the air above them has become an important medium of transportation, and they are as loath to let go any part of their possible rights as were the older maritime powers when rich sea routes had unexpectedly fallen into their hands. The control of air routes, and particularly world air routes, would be of inestimable value in time of war. They would aid in maintaining a strong aviation industry by offering a sure market for planes and would provide training and employment for specialized personnel. Such control could also become a ready instrument for spreading national influence, culture, and trade, particularly into the many areas now difficult of access by more conventional means of transportation. As Wayne C. Taylor, Under Secretary of Commerce, recently observed: "The world, especially in the far-off places, has never had enough transportation, and it will be many, many years before anything approaching saturation can occur." Though transportation routes tend to follow trade channels already established, the reverse is also true, and it will be interesting to observe how some of the radically different routes that may result from the characteristics of the plane will affect international trade and passenger movements.

Attempting to obtain a more nearly accurate definition of "freedom of the air," the joint air transport committee of British Chambers of Commerce, the Federation of British Industries, and the London Chamber of Commerce has presented three versions of the term. According to one version, it might be restricted merely to "freedom of air passage," permitting airworthy craft of any nation to fly over any other state provided they did not land. This freedom alone could be of considerable benefit to international air lines, particularly those in Europe, where many a sovereign state can be traversed by plane in a matter of 30 minutes or so. The story is told that the air force of pre-war Belgium was frequently embarrassed by its difficulties in laying out training and test courses which would adequately extend a fast plane yet keep it within the confines of the



TRAITÉ
ÉLÉMENTAIRE
DE CHIMIE,
PRÉSENTÉ DANS UN ORDRE NOUVEAU
ET D'APRÈS LES DÉCOUVERTES MODERNES;
Avec Figures:
Par M. LAVOISIER, de l'Académie des Sciences, de la Société Royale de Médecine, des Sociétés d'Agriculture de Paris & d'Orléans, de la Société Royale de Londres, de l'Institut de Bologne, de la Société Helvétique de Bâsle, de celles de Philadelphie, Harlem, Manchester, Padoue, &c.
TOME PREMIER.
A PARIS,
Chez CUCHET, Libraire, rue & hôtel Serpente.
M. DCC. LXXXIX.
Avec le Privilège de l'Académie des Sciences & de la Société Royale de Médecine.

Title page of the first edition of Lavoisier's epochal treatise on chemistry, publication of which at Paris in 1789 marked the formal beginning of modern chemistry

Harvard University Library

country. A broader definition might be "freedom of air facilities," meaning that registered airplanes could, without previous negotiation or notification, utilize foreign airports, weather reports, radio beams, fuel supplies, and so on, just as ships of all nations can take advantage of port and coastal facilities. Finally, the term might be made to cover "freedom of air trade," so that properly registered planes might carry passengers or freight between any two points on the globe where a profit could be gained. Conceivably a plane owned and manned by Greek nationals could then maintain a schedule between Cincinnati and Toronto without let or hindrance.

A truly open sky should greatly simplify the establishment of international air routes, for aside from the fact that such a policy would give maximum scope to the most efficient and enterprising lines, the map gives an altogether too optimistic impression of the number of alternative routes open between the various world centers. Geographically feasible routes may be impractical because they avoid large population centers or regions rich in resources, because they are unsafe, because they involve hops beyond the economic range of transport planes, or because of many other difficulties. Thus inability to obtain the use of one landing field might make it impossible for a line to maintain a coherent schedule.

Not only are natural obstacles easier to accept than political obstacles; the natural obstacles have a way of yielding to engineering progress with surprising rapidity. For example, the stretch across the northern Atlantic between the United States and Europe, though not impossible, is too long a hop to be altogether attractive to commercial planes. The Pennsylvania-Central Airlines has applied for permission to fly this route using three floating steel platforms, or seadromes, 800 miles apart. These seadromes, each containing in the order of 64,000 tons of steel and standing 70 feet above the water, would be buoyed to remain steady in the most violent sea, yet would be shifted as occasion demanded, so as to remain outside fog and ice zones.

Anent Antoine Lavoisier

BY HEWITT G. FLETCHER, JR.

THE coming August 26 marks the 200th birthday of Antoine Laurent Lavoisier — the "Lavoisier of immortal memory," founder of modern chemistry, and victim of the Reign of Terror. Next year it will be 150 years since Coffinhal of the tribunal (so tradition says) voiced his cynical blindness with the oft quoted sentence: "La République n'a pas besoin de savants, il faut que la justice suive son cours." (How the Twentieth Century mocks those unfortunate words!) Standing here as we now do before these two anniversaries, we can fairly ask: What did Lavoisier really accomplish? What is the final verdict of posterity? In the last century and a half, many opinions have been expressed on this subject, for the character of the man and his work was such as to admit doubts in the minds of some. Unfortunately Lavoisier had only just accomplished the revolution in chemistry when the maelstrom of the contemporary political revolution sucked him down and prevented him from defending the new regime which he had instituted. The majority certainly gave the man his due; their sentiments were spoken by the mathematician Lagrange, when he said to Delambre on the day following the execution: "Il ne leur a fallu qu'un moment pour faire tomber cette tête, et cent années peut-être ne suffiront pas pour en reproduire une semblable." Others were less ardent, and the cause of their diffidence touches the nature of Lavoisier's true greatness.

Lavoisier belonged in the more select of the two classes into which scientists may be ranged. One of these classes is composed of the factfinders, the fine experimentalists who prefer to tinker in the laboratory and explore simply for the joy of exploring. In matters of theory, they are either uninterested or strictly conventional. Joseph Priestley, to name one of Lavoisier's contemporaries, is perhaps the ideal example of this type. He was a delver (not in the dilettante sense), adept and contented in the laboratory but, until death, a strong and inconvertible phlogistonist. The dissenting minister was, as someone has remarked, as orthodox in his chemical doctrine as he was heterodox in his theological one.

The function of the second class of scientists complements that of the first. They may be called the theorists — men not interested in facts as such but rather in the grand scheme behind the facts. In the laboratory they are often less adept than the factfinders (thus Priestley and Scheele were far superior to Lavoisier), but their object is different; far from being curious explorers, they concentrate on a few experiments expressly designed to illuminate and correlate whole groups of phenomena. Both classes are as essential to the healthy

growth of science as explorers and homesteaders are to the proper development of a newly discovered land. It is the second of these two classes, the theorists, to which Lavoisier belonged. When one reads his papers, one is repeatedly struck by the thought that he seemed to know in advance where he was going and just what he wanted to prove. At an early stage he glimpsed, dimly, some logical structure behind the mass of recorded phenomena relating to combustion, and from then on he worked only to prove the existence of that structure — not to himself (he seemed quite convinced of it) but to others. In his most famous experiment, wherein he demonstrated that the gain in weight of tin on calcination was equal to the weight of the air consumed, he could report but two trials in which some accident, such as cracking of the retort, had not occurred, and the trials yielded only mediocre quantitative results. Yet, withal, he drew the right conclusion and went on to consolidate the theory of combustion.

How these two classes of men might nettle each other is easy to see. The laborious factfinders were (this is less true today) hardly pleased to find their dearly won facts niched in a structure developed largely in the head of a theorist. Moreover, they could not help feeling that the structure was theirs, for had they not contributed the substance of it? Such was the situation with Lavoisier and his contemporaries. Of course, Lavoisier contributed a large portion of the facts with which he brought about the revolution in chemistry, but some of the most important ones he owed to his contemporaries and these facts he sometimes took without giving proper credit to the discoverers. It was this appropriation of facts which occasioned the rancor that detracted somewhat from Lavoisier's reputation; it was in part a reflection of the ungenerosity of the age. Who can say whose was the greater contribution, Priestley's in discovering "dephlogisticated air," or Lavoisier's in recognizing the role of that substance in combustion and naming it oxygen? The capstone of Lavoisier's system also came from another. Henry Cavendish found that water is composed of "inflammable and dephlogisticated airs." Hearing of the discovery from an associate of Cavendish, Lavoisier saw the completing piece for his whole system — a piece for which he gave Cavendish little credit. A thoroughgoing theorist, Lavoisier seemed to care only for the system.

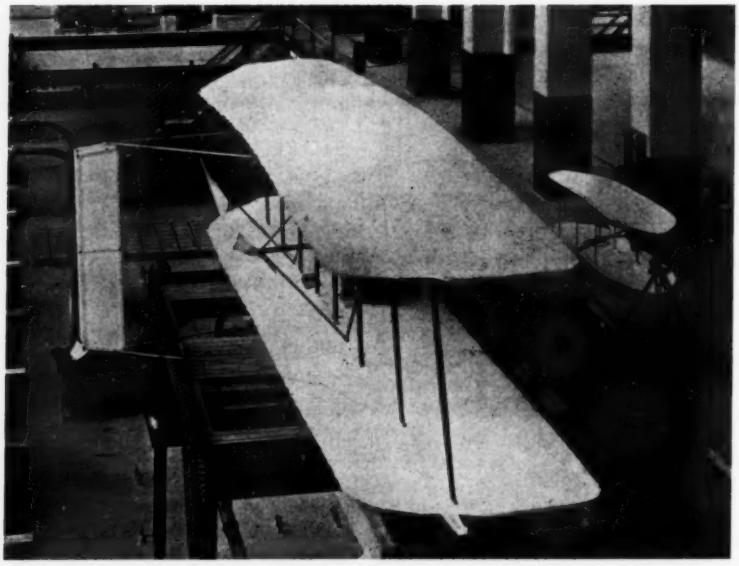
By 1789, when he was 46 years old, Lavoisier had overthrown the phlogiston theory and established modern chemistry, essentially as we know it. In that year he published his *Traité élémentaire de chimie*, the first textbook written from the point of view of the new system and marking formally the advent of it. The work is lucid and intelligible to the present-day chemist — a statement which can hardly be made of those works which preceded it. Five years later, in a basket on the scaffold in the Place de la Révolution lay the author's head, symbol of the most unthinking act of the revolution.

After the revolution, Lavoisier's memory was defended vigorously by his countrymen, with whom the new system became almost a nationalistic instrument. The literature about him became voluminous. Some of it, such as Hermann Kopp's account in his great *Geschichte der Chemie* (1843–1847) was scrupulously fair; other writers were critical and shortsighted. With the latter belongs Adolphe Wurtz, a French Alsatian, who began his *Histoire des doctrines chimiques* (1868) with the words, "La chimie est une science française. Elle fut constituée par Lavoisier, d'immortelle mémoire." These inflammatory sentences stirred up an acrid polemic with the chemists across the Rhine (represented chiefly by Jacob Volhard), who went as far in the opposite direction to discount the value of Lavoisier's accomplishment.

Shakespeare to the contrary, the good in Lavoisier was not buried with him; indeed, his worth seemed to draw greater appreciation from year to year as minor disputes were forgotten and the stature of the man stood revealed. The train of scholarship and appreciation really began with Edouard Grimaux, whose extensive but uncritical life of Lavoisier first appeared in 1888. This work, based directly on the many documents which Lavoisier left, is still the main source of material on his life; it fails, however, to describe his scientific contribution in detail. A first attempt at appraisal of Lavoisier as a scientist was made in 1890 by the great chemist and historian, Marcellin Berthelot, in his *La Révolution*

The Bettmann Archive

Lavoisier and his wife, from a painting by J. L. David. Born Marie Anne Pierrette Paulze in 1758 and wed to Lavoisier when she was 13, Mme. Lavoisier was of great aid to her husband in keeping records, making drawings, and translating English works for his use. Her qualities as a hostess made their home a mecca for Parisian society. Some 11 years after the execution of Lavoisier, she became the wife of Count Rumford, but their temperaments were incompatible, and the union ended in amicable separation in 1809. Her death occurred in 1836.



The famous airplane with which the Wright brothers achieved successful flight at Kitty Hawk, December 17, 1903, as it appeared when exhibited at the opening of the Institute's Cambridge buildings in 1916

chimique: Lavoisier. The Twentieth Century has seen the completion of these studies, particularly at the hands of the late A. N. Meldrum of Gujarat College, Ahmedabad, India, and Douglas McKie of London. During the last few years the work of these two men has culminated in the appearance of two biographies of Lavoisier. We are fortunate in having them on this 200th anniversary, for not only do both furnish fascinating reading but they represent, in a sense, the final verdict of history.

The first one to appear, by McKie,* is a meticulous, clear-cut, fine-grained examination of Lavoisier's chemical achievements. In the first and final chapters, it contains all the essential facts of the man's life, but these are subordinated to his works. The scientific background of his day, especially with regard to the works of his contemporaries — contributions which played so large a part in his new system — is filled in with all requisite detail, and Lavoisier's own writings, so confusing in their chronology, are analyzed with a skill which makes this book the model of what a chemical biography should be.

The second of these two biographies† is by Sidney J. French of Colgate University. It represents an attempt to deal in a balanced manner with all the aspects of the man — his activities as a man of society, financier, reformer, economist, politician, inspector of gunpowder, geologist, physiologist, and chemist. The work is written in an imaginative, popular style and describes in some detail the cultural, political, and scientific scene in which Lavoisier lived. The author takes the liberties of a novelist with the known facts of Lavoisier's lineage and furnishes a lively picture of his antecedents, without, however, obscuring the known with the fancied. Of particular interest to Americans is the connection between the Lavoisier and Du Pont families, which is here described for the first time in a biography of Lavoisier.

With these two works, chemists at last have at hand as much information about the founder of their science as physicists have about Isaac Newton.

The Wright Brothers

IN the long roll of man's inventions, the most momentous, in terms of human aspiration, is the achievement of flight. The event at Kitty Hawk on December 17, 1903, was more than the fruition of the long, persevering, and selfless research which stands to the eternal credit of the two brothers who worked so well together, and to the credit of a uniquely understanding father. The past century and a half — invention's heyday — have seen a considerable number of mechanical, electrical, and other creations brought into being through comparable efforts of consistent, hard-driving, comprehensive research. The endeavor which Orville and Wilbur Wright brought to successful culmination at Kitty Hawk 40 years ago was a distinguished example of this kind of directed exercise of the intelligence. But its greater significance lies in the fact that the 12 amazing seconds at Kitty Hawk that day were, in Orville Wright's words, "the first in the history of the world in which a machine carrying a man had raised itself by its own power into the air in full flight, had sailed forward without reduction of speed, and had finally landed at a point as high as that from which it started." The most ancient of man's conscious aspirations, charged with many kinds of historical and spiritual values, had reached its consummation in that dramatic fact.

Fred C. Kelly's biography of the Wright brothers‡ is not the definitive history of that achievement. To say so is not in the least to disparage Mr. Kelly as a reporter; it is rather merely to recognize the great difficulties under which any historian must labor whose task is to treat of world-shaking events before time has allowed the whirlwinds to subside. Objective, factual, and detailed, Mr. Kelly's book is an extremely valuable assemblage of the elements in the drama, and on this count its value is enhanced by the fact that the author had in his work the interest and support of Orville Wright, who read the manuscript and verified the accuracy of statements.

Two portions of the story as Mr. Kelly tells it are particularly to be noted. The one is explicit: his good-humored but unsparing survey of how the fourth estate in 1903 shrugged a skeptical shoulder at the biggest story of the year. Harried (*Continued on page 510*)

* *Antoine Lavoisier; the Father of Modern Chemistry.* Philadelphia: J. B. Lippincott Company, 1936.

† *Torch and Crucible; the Life and Death of Antoine Lavoisier.* Princeton: Princeton University Press, 1941.

‡ *The Wright Brothers; a Biography Authorized by Orville Wright.* New York: Harcourt, Brace and Company, Inc., 1943. 340 pages. $3.50.

The Next Decimal Place

War's Reliance upon Mathematics Spurs a Renaissance in Mathematical Studies, Emphasizing Applications

By George W. Gray

ONE day in 1941, according to a story out of England, a nazi shell from across the Channel hit near Dover and killed several civilians out of a crowd gathered to watch a tennis game. Before it reached the ground, the projectile passed through a zone of foliage, snapping off the branches of several trees and underbrush. As the story goes, two British mathematicians measured the angle of path indicated by the snapped branches, from this they calculated the trajectory of the missile, and thereby they worked out the probable position of the gun on the French Coast. Then a Royal Air Force plane went across and dropped bombs on the indicated spot, and thereafter the gun was silent.

The major contribution of mathematics in this incident was not the service of determining the path of the shell back to its source. That was a fairly routine problem in ballistics. A greater achievement was that represented by the design of an airplane able to rise from the ground with a heavy bomb load, fly a given course with sureness and dispatch, and from miles up lay its deadly parcels on a dot on the map. There is of course an element of luck in every hit, but the performance of the plane and of the bombardier is to be credited to mathematics no less than it is to the gasoline which propelled the plane or to the high explosive which powered the bomb.

For all these weapons which we have called gifts of physics are equally gifts of mathematics. If mathematics is queen of the sciences, as Gauss declared more than a century ago, perhaps physics may be called king. Archimedes, Newton, Gauss himself, Clerk-Maxwell, Einstein, and many other creative scientists exemplify in their work the fruitful collaboration of mathematics and physics. Their equations not only guided and tested their physical discoveries but also in many instances gave the first clue, the spark which was fanned into flame by experiment. Though many important inventions have been stumbled upon or were first crudely conceived by experimenters ignorant and in some cases contemptuous of the mathematical techniques, rarely has an invention been brought to full utility without the application of mathematical analysis to the problems involved in the design of it. This condition is particularly true of the complicated high-speed machines of today, including those on which we rely for victory in warfare.

The branches of physics which have borne the brunt of the struggle — ballistics, aerodynamics, optics, acoustics, and electronics — have derived much of their improved facility and accuracy from men working with paper and pencil to increase the approximation of perfect design to the next decimal place. Their work, in turn, rests on the heritage of observations, theorems, demonstrations, and techniques which have come down through the centuries.

It is the progressive mechanization of war which makes the need for mathematics and mathematicians so insistent. As weapons become more speedy in operation and more forceful in the blows they deliver, standards of precision in the construction of them and standards of accuracy in their performance become ever more exacting. A minor departure in aircraft shape which makes no serious difference in a plane moving at 200 miles an hour may add a prohibitive drag when the plane moves at 400 miles an hour. As the velocity and altitude of flight increase, the speed of operation of antiaircraft defense must be increased still more. This factor means cartridges built to specifications measured in ten-thousandths of an inch instead of mere thousandths, shells streamlined for the minimum of air resistance, and time fuses correct to the four-hundredth part of a second. Many of these devices must be made and assembled in air-conditioned factories because dust and temperature changes are silent saboteurs of the new instrumentation. Narrow margins of error may be decisive between defeat and victory — and the determination and control of these slight differences lie within the scope of applied mathematics. Old easygoing methods of cut and try not only are wasteful of time, labor, and materials, all so precious in war, but may miss the goal altogether.

Aircraft may attain a particular speed at which the wings will vibrate in a violent and self-destructive manner known as "flutter." One of the problems of design is to make sure that the highest speed at which the plane can be flown is less than this critical flutter speed. To investigate this question one may build a specimen plane or a small-scale model and test it in a wind tunnel. Or the specimen plane may be tried out in the air by a test pilot. But both methods require labor and material, to say nothing of time, and such flight testing is very dangerous. Nor are these experimental procedures possible in the initial stages of the design of a plane. By means of applied mathematics, however, one can predict the critical speed at which a wing of a given type, shape, and size would develop flutter. Moreover, through the use of the results of mathematical analysis, favorable departures in design can be discovered and theoretically explored with the plane still in the blueprint stage.

After a design has thus been worked out, a model may be built for testing in a wind tunnel — and here again mathematics becomes an indispensable tool. For suppose the model is one-fourth, one-third, or one-half the full size — how can one determine from the performance of the model what the performance of the full-sized plane

will be? Aerodynamics has many variables, and its physical laws require mathematical formulation to enable the aeronautical engineer to infer the actual flight performance from the wind-tunnel performance of a small-scale model.

Many of the complicated mechanisms, instruments, control devices, and auxiliary equipment which are necessary for the proper functioning of the aerial warship are subjects for applied mathematics. An example is the gyroscope, which operates in the automatic pilot, the compass, turn indicator, and other devices. The employment of it in such equipment can be understood and engineered only by persons familiar with that branch of applied mathematics known as dynamics.

Another important branch of applied mathematics is the theory of elasticity, which embraces our fundamental knowledge of the stretch of materials under load. Those who design artillery, tanks, warships, airplanes, and armor plate rely indirectly on the mathematician for formulas which will enable them to predict the behavior of materials from tests made on specimens.

Electrical circuits and electronics are territory for the mathematician. Without his aid the highly complicated devices of military communication, aircraft and ship detection, and gunfire control would be far more limited than at present. Several of the advances in telephone communication were mathematical inventions: The single side-band system of carrier transmission, for example, which doubled the number of long-distance calls that could be handled over one line, was the outcome of a single trigonometric equation. The design of electric filters and equalizers also was born of mathematics. "Mathematics," declared an authority of the Bell Telephone Laboratories, "has been as essential to the development of nation-wide telephony as copper wire or carbon microphones."

One fascinating field of mathematics which finds important application in war is the theory of probability and of mathematical statistics. The applications of probability to artillery fire are classical; but in the present conflict the emphasis on bombing, on submarine hunting, on antiaircraft destruction of airplanes, and on battles in the air all give rise to a great variety of important problems in which the laws of chance play a vital role. Some of these problems are highly complicated and involve so many factors that the actual computation of results requires weeks or months, even when the most powerful modern computing machines are used. In a war of the present type, one can trace a very real connection between the success of the superb Russian offensive and the fact that a Stalin Prize is given for a paper entitled, "On Dispersion, Probability of Hits and Mathematical Expectation of the Number of Hits."

The varied mathematical resources which have been suggested thus far are all comparatively recent arrivals on the American scene. When the American Mathematical Society was organized in 1888, it could muster only six members. Not until after the turn of the century did a few universities begin to acquire men of high professional rank in this science, and their tendency was to magnify the theoretical aspects to the neglect of practical applications. Harvard developed an exceptional group for research and teaching, to be followed by a similar development at the University of Chicago and then, about a dozen years ago, by the establishment of the Institute for Advanced Study at Princeton. These three centers have become fountainheads of mathematical study and by the 1930's had attained a position of world leadership in pure mathematics. In addition to these three powerful faculties, a dozen other American universities had departments strong both in teaching and in research, but with rare exceptions they exalted the theoretical.

The layman might suppose that if a person knows mathematics, he ought to be able to apply it to any problem subject to mathematical treatment — but the situation isn't so simple. Professor S. R. Williams of Amherst tells of an engineer in a large industrial research laboratory who confessed his inability to cope with certain problems despite the fact that he had been trained in the calculus, vector analysis, elliptic integrals, complex variables, and modern theories of differential equations. "The trouble, as he saw it, was that the courses were given by mathematical instructors who placed too much emphasis on manipulations and neglected or ignored the applications to practical problems." This engineer appealed for help to four different professors of mathematics. Three of them failed to provide the needed solution, but the fourth man, who was able to see the correspondence between a physical situation and its mathematical form, succeeded.

In 1938, the National Research Council was asked by the National Resources Planning Board to make a survey of scientific, industrial, and business research in the United States. One of the subjects up for consideration was the resources of mathematics for industrial research, and for this the council turned to Thornton C. Fry, mathematical research director for the Bell Telephone Laboratories. His resulting report, "Industrial Mathematics," provided a critical review of the entire field. In it the author discussed the many uses of and needs for mathematics in industrial research in contrast with the fewness of fully trained industrial mathematicians. "Though the United States holds a position of outstanding leadership in pure mathematics, there is no school which provides an adequate mathematical training for the student who wishes to use the subject in the field of industrial applications rather than to cultivate it as an end in itself," said Dr. Fry. "Both science generally, and its industrial applications in particular, would be advanced if a group of suitable teachers were brought together in an institution where there was also a strong interest in the basic sciences and in engineering."

Not all have entirely agreed with these statements. Some disagree with the extent to which Dr. Fry identified "applied mathematics" and "industrial mathematics." Others think he was too pessimistic about the state of applied mathematics in this country in 1940, the year the report was published. But the timely challenge presented by his article, combined with the developing necessities of the war, is surely resulting in a great change of emphasis. A recent President of the American Mathematical Society, himself a pure mathematician of great distinction, has argued for a "renaissance of applied mathematics" and has (*Continued on page 496*)

The Skillful Skull

Man's Brain Case, in Its Ability to Resist and Dissipate Manifold Stresses, Is a Noteworthy Example of Efficient Architecture

By M. F. Ashley Montagu

THE human skull is not often thought of in architectural terms, yet it probably represents one of the most perfect examples of a structurally efficient piece of architecture ever developed. If, for convenience, we may speak teleologically, it may be said that the purpose of the skull is to afford support and protection for the brain and for most of the organs of sense. Such a bony structure must be able to resist stresses and strains of all sorts and must be so constructed as to enable the forces acting upon it to be innocuously distributed. The skull fulfills all these requirements perfectly.

The only movable portion of the adult skull is the lower jaw. Normally, it is entirely through the action of the lower jaw upon the upper jaw that stresses are produced upon the skull as a whole. Since every movement of the lower jaw which brings its teeth into contact with those of the upper jaw produces a series of more or less powerful stresses that may affect the whole skull, the latter must be perfectly adapted to receive the thousands of assaults which are every day made upon it.

Not alone through the teeth does the lower jaw act upon the skull but also through the agency of the powerful temporal muscles, which are attached to the upper side walls of the skull and extend from the temple to a little distance above and behind the earhole. When the mouth is opened, the muscles exert a pull upon the skull; when the mouth is closed, they exert a compressive force. In addition, there are the masseter muscles, which arise from the arch of the cheekbone (the zygomatic arch); and the pterygoid muscles, which arise from the pterygoid pillars on the base of the skull. All these muscles pull and push upon the bony structures to which they are attached. Supported and moved in all directions by these muscles, the lower jaw (or mandible) is freely hinged by a capsular group of ligaments to a more or less shallow depression, the mandibular fossa, into which the head (or condyle) of the mandible is received immediately in front of the earhole. The reader, by opening and closing his lower jaw and by moving it from side to side, will be able to confirm for himself how freely movable is the head of the mandible and how great, in consequence, must be the variety of forces which act upon the skull. In front of the head of the mandible is a shallow notch, which terminates in front in an inverted pyramid of bone, the coronoid process.

Separated by the mandibular notch, therefore, are two processes surmounting the perpendicular portion, or ramus, of the lower jaw: the coronoid in front and the condyloid, or head of the mandible, behind. The powerful temporal muscles are attached to the coronoid process and to the front border of the ramus of the lower jaw. The mandible thus is a lever, with its fulcrum corresponding to the condyle at the mandibular joint — that is, the joint formed by the head of the lower jaw together with the mandibular fossa in the temporal bone on the base of the skull. The force is exerted through the coronoid process and along the front border of the ramus of the lower jaw, while the resistance is distributed along the upper border of the tooth-bearing, or alveolar, portion of the body of the mandible, in which are lodged the roots of the teeth. The relationship among all these structures — the teeth, the tooth-bearing body, and the coronoid process — though commonly overlooked, is one of the most intimate nature.

Observing the kind of structural changes that occur when some of the normal relationships among these structures are disturbed brings into high relief the distribution of the moments of force of normal stress and strain. An opportunity of observing how the abnormal may throw light upon the nature of the normal is also thus afforded.

Normally, when the lower jaw is closed upon the upper jaw, or maxilla, the first structures to meet are the first molar teeth of the upper and lower jaws, followed by the second molars and the first and second premolars, and finally by the third molars and the incisor teeth. The peculiarity of this series of contacts is due to the fact that the occlusal, or biting, surfaces of the teeth — reflecting the conditions of the tooth-

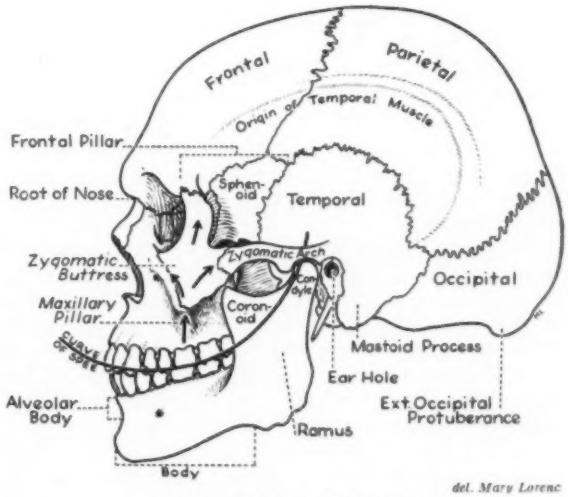


Fig. 1. The left side of the skull

bearing portion of the jaws — are arranged upon a curve, the so-called curve of Spee, which approximately corresponds to the arc of a circle drawn tangential to the outer cusps of the teeth. In the female this curve more nearly approximates the arc of a circle than it does in the male; hence the somewhat more "pert" appearance of the front of the upper jaw and its teeth in the female than in the male. If this curve is prolonged backward, it normally passes through the front border of the condyle of the lower jaw when the latter is at rest (Fig. 1). Thus the arrangement of the teeth is continuous with the path of the condyle or concentric with it, so that both can move around the same fulcrum.

Since the biting surfaces of the teeth do not present plane surfaces but are broken up into elevated cusps and depressions — the cusps of the lower teeth fitting into the depressions of the corresponding teeth in the upper jaw and vice versa — an efficient method of enabling the teeth to move upon one another would be to arrange them on both sides of the arc of a curve, on much the same principle as the cogwheel works. Far more efficient than the cogwheel, however, is the existing arrangement, for the curve of Spee allows the teeth to move upon each other in a great many directions. The lowest point of the curve of Spee is situated at approximately the middle of the first upper molar tooth. This, interestingly enough, is the second permanent tooth to erupt (at 6.4 years in boys, 6.1 years in girls), the first permanent tooth being the first molar of the lower jaw, the so-called six-year molar (acquired at 6.3 years in boys, 5.9 years in girls).

The first upper molar is subject to the greatest amount of stress and strain and, incidentally, it is this tooth which is generally the first to become diseased and the one which is the earliest and most commonly extracted. The arrangements for distributing the forces acting through this tooth may now be described.

Architecturally the skull more closely approaches the Gothic style than any other, for the skull is best regarded as an arch or series of arches, the pillars of which are supported and reinforced by a number of buttresses. The three main arches are formed respectively by the frontal, parietal, and occipital bones and run from side to side; while the great sagittal, or principal, arch runs from the root of the nose to the back of the head, the whole on a foundation which is somewhat weakened by the fissures and foramina into which it is broken up (Fig. 2). Fortunately for us the skull accommodates shocks in the same manner as do all architectural arches: Instead of passing directly to the base of the skull, the shocks are distributed through the supporting pillars and through the various buttresses. The pillars of the frontal arch are the zygomatic and sphenoid bones. Those of the parietal arch are the temporal bones. The mastoid processes are pillars of the occipital arch. The great sagittal arch is supported at the front of the head by the glabella — the thickening of bone between the supraorbital ridges — and at the back of the skull by the massive concentration of bone known as the external occipital protuberance, and by the basilar portions of the occipital bone. The pillars generally are flat bones, except for the most lateral part of the zygomatic pillar, which is relatively robust.

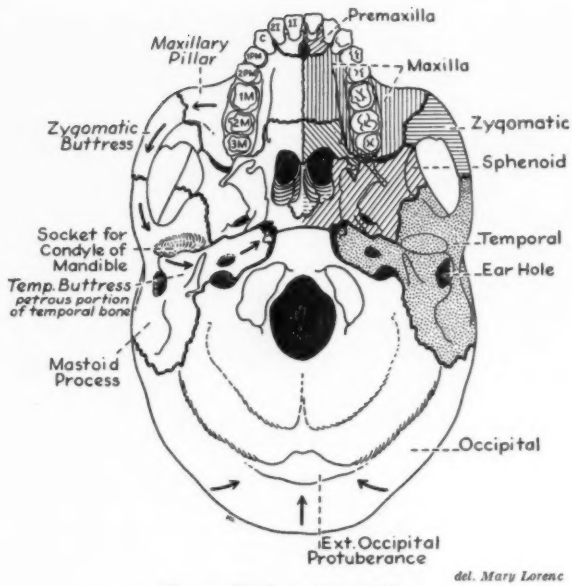


Fig. 2. The base of the skull

The key buttress of the whole skull is the quadrangular zygomatic bone, which lies against the frontal bone above, the upper jaw below, the sphenoid bone medially, and the zygomatic process of the temporal bone. These relations are displayed in Fig. 1. The important fact to observe is that the lower part of the zygomatic buttress lies in a significant relation to the upper jaw and to the first upper molar tooth. It will at once be seen that a pillar of bone derived from the upper jaw rises at a little distance above the first molar to join the zygomatic buttress. Through this maxillary pillar practically all the stresses arising in the upper first molar are transmitted. From this pillar, the stresses pass into the zygomatic buttress, where they are then distributed in all directions as illustrated in Figs. 1 and 2. In this way the forces are distributed throughout the skull without any injury to it or discomfort to the organism.

The structure of the bones themselves facilitates the accommodation of these forces since the bones are made up of two layers of dense bone between which is a layer of cancellous bone of spongy, or latticelike, structure (see Fig. 3). Thus forces traveling in the direction

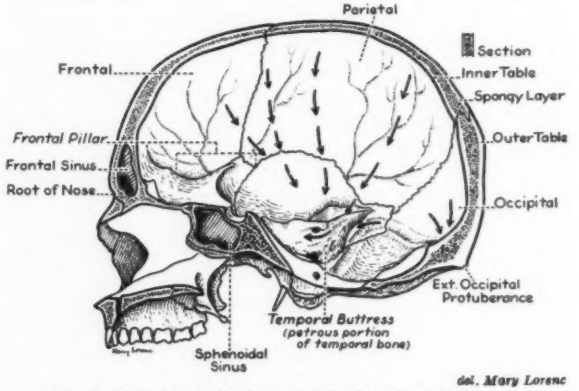


Fig. 3. The right half of the skull looking into the interior

Left: *Fig. 4. Right side of the skull of an American Negro, showing the loss of three molar teeth in the upper jaw and all the molar and premolar teeth in the lower jaw, together with the remarkable protrusion of the upper jaw. Evidences of an abscessed condition may be seen at the back of the upper jaw.* Right: *Fig. 5. The left side of the skull shown in Fig. 4. Here all the premolar and molar teeth of the lower jaw have been lost, and evidence of an abscess is seen in the premolar region of the lower jaw. Note how the upper teeth, meeting with no resistance from below, have migrated downward. Note also the shallowness of the notch at the top of the ramus of the jaw. Compare the angle made by the ramus and the body of the lower jaw with the same angle in Fig. 1.*

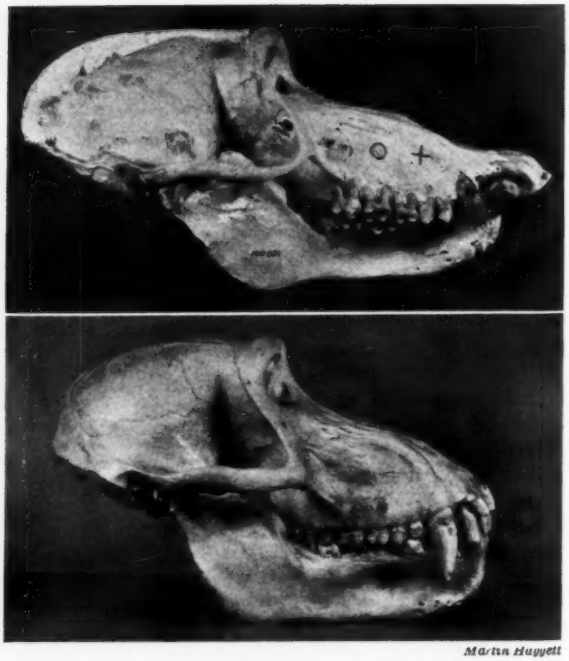
of the long axes of the bones will be greatly reduced by the dense layers of bone and will have a considerable amount of their energy dissipated by being sidetracked into the innumerable struts forming the spongy layer. Forces acting at right angles to the long axes of the bones will be diffused through the outer dense table and, if the forces are still powerful enough to reach the spongy layer, will be greatly reduced there, so that they would have to be powerful indeed to reach the inner table of the skull. The zigzagging latticework of the spongy layer very appreciably serves to take up and dissipate the tensive and compressive forces set up by the temporal muscles as they pull and press upon the side walls of the skull during opening and closing of the lower jaw.

What happens when some of the normal relationships of the structures of the skull are in any way disturbed is well illustrated in Figs. 4 and 5. Here we see photographic views of the right and left sides of the skull of an American Negro of mixed origin, about 45 years of age. It will be observed that the front of the upper jaw as well as the incisor teeth which it bears projects forward most abnormally. This projection exceeds by about 20 degrees that which normally occurs in the mixed Negro! This is a considerable deviation from the normal. Some years before his death, this individual had lost most of his molar and premolar teeth as a result of bad abscesses; in consequence, all the forces brought to bear upon the upper jaw were limited to the incisor teeth against which the lower incisors occluded. The constant pressure exerted against these teeth gradually forced the upper jaw and teeth upward and forward, while the angle between the ramus and the horizontal portion, or body, of the lower jaw enlarged so that the body and the lower teeth were projected forward. Instead of the upper teeth biting *over* the lower, an edge-to-edge bite was produced. Thus the lower jaw, superficially not appearing to have done so, suffered even more than the upper.

These are striking enough changes, but observe what has happened to the rest of the jaws and teeth: The two right upper premolars, not having any antagonists against which to bite, have grown downward as far as they could (Fig. 4). Similarly, all the upper teeth on the left side (Fig. 5) have descended way below their normal level. The tooth-bearing portions of the jaws from which the teeth have been lost have shrunk considerably. The maxillary pillar has disappeared; the coronoid process, the mandibular notch, and the width of the sidepiece, or ramus, of the lower jaw are much reduced; and the angle between the relatively perpendicular ramus and the horizontal portion, or body, of the lower jaw is greatly enlarged. The marked asymmetry of the vault of the skull may or may not have been produced by the same conditions.

This example serves to illustrate several important facts: Firstly, it is clear that the principal purpose of the tooth-bearing portions of the jaws is to give support to the teeth; and that when a tooth is lost, the alveolar portion of the jaw in which the tooth was lodged undergoes atrophy. Secondly, a tooth is not properly regarded as merely a biting organ, for it is an organ which is structurally and functionally interrelated with several others, so that any significant variations in it may be, and usually are, reflected in the adjacent structures. Thirdly, the form of the jaws may be considerably modified by changes in the distribution of stresses produced by the lower jaw after loss of certain teeth.

Facts such as these should teach us to look upon the loss of even a single tooth as a disaster to be avoided. The shrunken appearance of the jaws and the consequent accenting of the chin of old people who have lost their teeth are familiar to everyone. The Punchlike chin is explained by the fact that whereas the tooth-bearing portions of the jaw disappear, the base of the jaw remains unaltered; hence while the lips move inward, the chin stays put. George Washington, for instance, was practically toothless in his last years. Those acquainted with this fact may well be somewhat puzzled by portraits painted by Stuart and Peale, in which Washington's upper and lower jaws seem rather full at the lips. Of course, Washington wore an ivory denture, but that is not the explanation. The true explanation is simply



Martin Huyett

Above: *Fig. 6. Right side of the skull of a baboon* (Papio hamadryas) *suffering from rickets.* Below: *Fig. 7. Right side of the skull of a normal baboon of about the same age and species as that shown in Fig. 6 above.*

this: For the purposes of the portraits, and presumably posterity, cotton wool was stuffed under his lips in order to fill out his jaws! Modern restorative dentistry would have rendered such an artifice quite unnecessary.

Now let us reverse the conditions and observe what happens when the supporting structures of the teeth — the bone, the pillars, and the buttresses — break down. First, however, it will be necessary to discuss the structure of normal bone.

Bone is composed of white fibrous tissue impregnated with mineral salts. The mixture is so perfect that the size and shape of the bone remain unaltered when all the fibrous tissue is burned out of it or when all the salts are dissolved out of it by acid. The salts make up approximately 70 per cent of the weight of the bone, and about six-sevenths of that is calcium phosphate.

When a thin slice of bone is examined through the microscope, it is seen to be made up of multitudes of thin sheets closely applied to one another. These layers are called "lamellae." Among them may be seen a number of large holes, the Haversian canals. Beside them are to be seen several minute spaces between each two lamellae; from these lacunae run a number of fine canaliculi, which pass between and through the lamellae and connect each lacuna with its neighbors. During life, each lacuna is completely filled by a bone cell, or bone corpuscle; the latter is essential for the nutrition and life of the bone.

A large proportion of the bone lamellae are tubular and are arranged in groups of from 4 to 20 tubes placed concentrically, one outside the other. Each group is called a "Haversian system," and the tubes are called "Haversian lamellae"; the larger holes seen in section are the cavities of the central tubes of the systems, and each of the holes is called a "Haversian canal." In addition to the Haversian lamellae, there are two other kinds of lamellae: interstitial lamellae, which are set between the Haversian systems, and circumferential lamellae, which are at the surface of the bone and are laid down under the periosteum, one after the other, in widening circles. On the outside of the bone is the periosteum, a tough fibrous membrane which is the active agent in the making of bone while the bone is growing or being repaired. Bundles of fibers from the periosteum pierce the circumferential lamellae and are called "perforating fibers." Becoming calcified, they nail the lamellae together.

During life, these elements of the bony structure are in constant process of being renewed, a process that depends primarily upon the proper nutrition of the organism. The best-known example of the effects of malnutrition upon developing bone is the disease of rickets, during which the whole structure of the bone breaks down and the bone itself becomes soft. Being no longer capable of resisting the strains put upon them by the muscles, the bones become seriously deformed.

In Fig. 6 is seen the skull of a hamadryas baboon (*Papio hamadryas*) which, after having reached a healthy adulthood, developed the adult form of rickets (rachitic osteomalacia) following transfer to a zoological garden where it probably suffered from lack of sunlight as well as from lack of the foods to which it had been accustomed during its life in the wild. For comparison with this animal's skull, Fig. 7 shows another of the same age and species, but perfectly normal. In the skull of the diseased animal, the front teeth and the body of the upper jaw supporting them have been almost completely flattened out, the tusklike canines are splayed out laterally, and the molar teeth are bent at their roots and everted, so that the biting surfaces of the teeth point somewhat laterally.

Rarefaction of the bone in the ramus of the lower jaw has proceeded most in the portion below the condyle, where the bone is as thin as India paper. The condyles have undergone such changes as to give the impression of having "melted." Throughout the skull, the bone has become exceedingly thin and fragile. The rarefaction of the bone is due to the extreme absorption of salts, while the great weakening of the bone is clearly due to the breakdown of the Haversian systems and their associated structures. These conditions are strikingly reflected in the tooth-bearing portions of both jaws which, since they are no longer structurally able to resist the stresses transmitted to them through the teeth, have given way, together with the teeth borne by them, to the limits of the forces operating upon them.

When, in disease, the supporting structures give way, the structures supported do likewise. When supported structures give way, the supporting structures become disordered because their order is dependent upon an interrelated system of elements from which one cannot be altered or removed without altering or disturbing all the others. Thus, from the smallest elements to the largest the architectural system presented by the skull is a thoroughly interdependent one. Since the construction of the skull combines the (*Concluded on page 496*)

Barnum Began It

A Postwar Philosophy for Museums, Foreseeing Great Opportunities, Calls for Compromise with His Techniques

By Arthur C. Watson

IT is relieving these days to think occasionally of the law of compensation, to reaffirm our belief that the end of the present catastrophe will bring a mode of normal living seemingly more pleasant than ever before. The word "postwar" has borrowed the paradisaic meaning of oasis, so nourishing to the mirage-beset man in the desert; it is the kirk, the ivy tod, in the vision of the sea-worn mariner. Though economic readjustment is perhaps the most vital phase of postwar planning, yet cultural rehabilitation, the development of a new orientation, deserves serious thought, and the museum man need not be at all modest about the part he can play in it.

The preparedness of the museum man to meet the changes that will follow the war will be discussed here. The subject is of general interest because of the rapid progress in the ability of the museum to get under people's skin. Indeed, this ability developed so fast in the years preceding the war that the modern museum may be considered almost as a new factor in our culture. Is it too rash to prognosticate that this factor will reach its fulfillment with the coming of peace?

The "modernity" of the modern museum was begotten by a part acceptance of the view of P. T. Barnum. What Barnum contributed — and at the same time delayed — was a sense that the public were entitled to see what they wanted to see. He stood at one pole of the axis, of course, thinking of little more than the shekels and the means to get them; with him the means were the ballyhoo, the promotion of the bizarre, the big noise. He knew the art of luring his public, of satisfying them quickly, of shooing them off to that mysterious freak called the "egress."

The reaction of orthodox museum men to Barnum in his own day was something approaching abhorrence. To them, the word "museum" had degenerated, and in general their fear of leaning toward the art of the circus forced them to adopt a high-brow aloofness. It was a case of one extreme encouraging another, and not until the present generation did definite signs appear that the more respectable museums wanted to effect a compromise. Today the museum man knows that he must be something of a showman (though perhaps he hesitates to use the term) and that his first consideration must be to encourage a clientele, to meet their demands, and to answer their (generally unconscious) questions. He has found out that he can accomplish this educative purpose without debauching his art or scholarship and without changing the quality of his show. In a self-confident manner, he functions not by any means in the spirit of the musical-comedy director training his chorus but in the spirit of the host thoughtfully preparing a friendly welcome.

What, then, will be the people's questions and demands which properly can be considered by the museum man in the postwar years? First, the public will greedily want to know more about the lands and the peoples overseas — all over the world, practically. Our horizon has been broadening and intensifying. It will continue to do so during the long period of world-wide rehabilitation, in which Americans are bound to have an important role. Already, there is a marked increase in interest in geography, cartography, ethnology, an increase in world consciousness more down to earth, more curious over details, than ever before. In the last War our soldiers were mainly in France, a country too much like our own to arouse curiosity. But the deserts of North Africa and the jungles of the South Sea Islands challenge the imagination.

That this enlarging of the horizon will be one of the sure results of the war is significant to me personally because of what I have learned about the past of my home town, New Bedford. A century ago and more, when the whaling industry was carrying New Bedford ships all over the globe, all the families in this small Massachusetts port would talk nonchalantly of antarctic seal islands, of Latin-American ports and politics, of Fiji cannibals, of fogs in Bering Sea. No New Bedford sailor returning home after a three years' cruise could tell any tall tales to impress his beloved, for she already had heard them all. In our hothouses was the night-blooming cereus from the Sandwich Islands (we never used the modernistic name, Hawaiian Islands); in gardens occasionally children could ride on the back of a giant Galápagos tortoise; and in parlors were carved war clubs from the Marquesas, and letters from the descendants of the Bounty mutineers, whose only acquaintances were in New Bedford. Many a whaling captain visited Pitcairn, sometimes to leave his wife for a few months on the island so that she might have proper care in childbirth.

Something of this familiarity with the truly foreign lands can be renewed, on a much wider basis, during the postwar years. The very fact that our soldiers and sailors have seen the exotic life will give the public an interest more zestful than could possibly arise from cold theorizing over internationalism.

Though the art museum can perform an important function in presenting the creative side of foreign culture, it can perhaps perform a still more important function in exhibiting the best of the art that is arising

out of the war and the best that will be influenced by the social forces in the postwar era. Art has traveled a long way from the periods when its greatest efforts were devoted to religious inspiration or to the glory of kings and emperors. Modern tendencies are democratic and show a sensitiveness to the living world which meets the public and the age squarely and honestly.

A second broad interest which people will have after the war will be a desire to discover the secrets of the "secret weapons" and their effect on the battles and the campaigns. Herein lies the great opportunity of the technological museums. It is true that almost all wars have had their secret weapons. The wooden horse of Troy — with a slight stretch of the imagination — can fall into the category. Many of the Roman engines, the Greek fire of Constantinople, the first gunpowder, the first fire ship — all of these had devastating and demoralizing effects on the enemy. The important fact about the present war is that it arrived when our science had reached a rich maturity and when the new theory of the blitzkrieg included surprise in all its phases as well as speed.

Apart from the secret weapons, whatever they may be, the known new weapons bear an import as yet only faintly perceived. We are amazed when we sense the revolutionary changes in warfare — more revolutionary than the changes announced by the battle between the *Monitor* and the *Merrimac*. We marvel at the advances science must now be making — we, who had considered ourselves rather blasé about such progress. We marvel at our productive capacity, born of the emergency but reared on an internal economic organization more sound, more elastic, more potentially energetic, than we had realized.

What, now, is the ultimate import of our material achievements, our scientific and industrial victories? This is another question the people will be asking, and they deserve a hopeful answer, hopeful proportionately to their patriotism and their patience, qualities of which they will be well aware when the struggle is over. How will the scientific swords of this war, those of friends and foes alike, be beaten into plowshares? How will industry, more self-confident now than ever before, respond to the desire for an improved world? Will the law of compensation be allowed to function freely and strike a balance for two great world wars?

These questions, and more of similar significance, can be answered in part, at least, by the museums. The modern techniques of exhibition, responsive to the times, will solve the problems of presentation. Within the century — within the decade, in fact — these techniques have rapidly matured. One used to think of the typical museum as a forbidding, never ending, dingy repetition of showcases containing the lifework of some gentle, scholarly biologist who classified, arranged, and studied his specimens for days without end. The biologist would be the curator, true to the derivation of his title — "one who cares for." Or else one thought of the typical museum as the haunt of some fond antiquarian, rummaging through his powder horns, shoe buckles, and yellowed documents, and trying out every visitor in the vain hope of finding someone who might share his single interest.

I once visited in Quebec a small historical museum connected with a convent. The museum was cluttered with relics of every description. The sister in charge tried her best to display her treasures and to be generally helpful, but the objects she sought had a way of hiding themselves, to be found only through stumbling over them or through tipping neighboring objects off the shelf. She loved her collection, but she was tired. "Oh, dear," she kept saying, "too many things; too many things!"

The plight of the elderly sister is shared — in spirit, at least — by many a museum man of the modern school. The collector tends to value his collection by the number of items. When the collector and the exhibitor are one and the same individual, a sacrifice of personal feelings has to be made. The art of the exhibitor is like all other arts: It implies judicious emphasis, and judicious emphasis implies judicious, and at times wholesale, omission. Without such omission the art museum becomes a bazaar, the historical museum a junk shop, and the natural-history museum a three-dimensional encyclopedia. The wise museum man changes his exhibits frequently; what he omits today, he brings out of hiding later; his institution acquires an atmosphere of freshness and life.

In connection with the typical modern museum one thinks of orderliness and simplicity, fluorescent lights and labels easily read, and a general "company's coming to dinner" atmosphere. The curator has left his microscope and dusted himself off. He has discovered that he wants guests — not guests who will accept him as is, but guests whom he will have to make a special effort to please and whom he must not weary at the very start.

One phase of the new museum technique has been the emergence of the idea of a "theme." The very idea that a theme is needed indicates a desire on the part of professional exhibitors to do something better than heretofore. Obviously an exhibit of, say, Colonial portrait painters carries its own justification and has its own ready-made theme; such exhibits will always have a place in our culture. There are other types of exhibits, however, which may well profit from a definitely pointed orientation, especially if it has a very personal appeal, inspiring the one who plans as well as the one who views.

The New York World's Fair of 1939 was an orgy of exhibition techniques of daring nature. From the museum man's point of view it was a monumental set of experiments, out of which were to emerge ideas and methods well worth the study for future reference. The New York Museum of Science and Industry, of which Robert P. Shaw, '23, is director, conducted a scientific survey of the fair's techniques, for the purpose of sifting out the wheat from the chaff.

Mention of the New York Museum of Science and Industry leads to consideration of another important trend, for that museum has been an energetic leader in the promotion of the "special exhibit." There is a definite appeal in the "something new," in the atmosphere of healthy living which comes from repeated change. The procrastination of a community dweller tends to keep him from viewing that which he knows will always be with him; yet he is potentially interested, perhaps keenly so, as is clearly proved by his tendency to visit a show of definite duration. (*Continued on page 508*)

First Voyage

How Temporary Orphancy from Formal Education Sped Elihu Thomson's Career—a Note for Schoolmen to Ponder

By David O. Woodbury

At the age of 11, Elihu Thomson passed his entrance examinations to the Central High School in Philadelphia — and was refused admission. Like many similar institutions, Central High functioned as a college, graduating its students after four stiff years of study directly into business and professional life. For a boy of 11 to enter its courses was out of the question. The lowest possible age for freshmen was 13, and even this was considered too young. As a consequence, Elihu was left a temporary orphan by the education system of the day.

His orphancy turned out to be a stroke of good luck. Using this unexpected gift of freedom, he laid the basis for a career which brought him fame throughout the world and elevated him to the rank of the foremost American scientist of his day. When Elihu Thomson died in 1937, then in his 84th year, he held nearly 700 patents, many of them basic to our present way of life. He had become a model for inventors and research men everywhere, a great thinker in many fields, and an educator whose genius for inspiring others had been signalized by his service as acting president of M.I.T. Most of all, he was beloved and revered by thousands, great and small.

It is interesting to look back for a moment to this formative period in the life of a great American to see how early freedom from routine helped in the flowering of his talent. In the story may be a strong hint that formal education can well be dispensed with, at least temporarily, when a pupil of independent mind becomes restive and wants to strike out on his own.

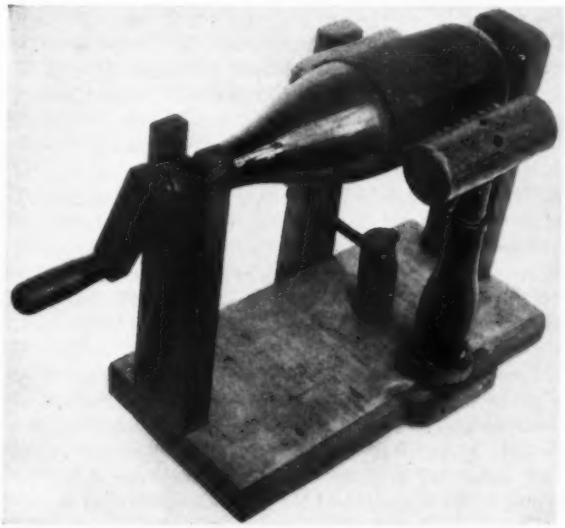
In the normal course of events, Elihu would have been required to repeat his grammar school studies for two years. But his teacher, George Stuart, had the wisdom and the courage to prevent this folly. It would do the boy good, said Stuart, to close his books for a time and catch up on recreation. Studies could wait. But he underestimated the mental hunger which had made young Thomson ready for higher education at 11 years. "Close my books?" the boy cried. "I would rather die!" It was not extravagance, but the rebellion of a mind keen beyond its years.

When Elihu reached home with the news, his conventional father was scandalized. But his mother rejoiced. She knew her son's capacity for original observation, his eagerness to explore nature and understand it. The enforced vacation was a boon, she said, such as few boys ever had. Elihu should have all the books he could read. He should build and experiment to his heart's content; he should have opportunity to find out "the go" of everything about him, just as James Clerk-Maxwell had done before him.

Thus, at a crucial moment in his development, a wise teacher and a sympathetic mother made him the rare gift of complete personal freedom. Like Tom Edison, who had been expelled from school because he was "addled," young Thomson escaped the shackles of unimaginative schooling in the very years when a private voyage among the mysteries of science could most powerfully formulate his ambitions. When he did go back to school, he had already set himself such a furious pace of research and invention that it carried him on without pause for 70 years.

The possessor of fabulous liberty, 11-year-old Elihu immediately became the envy of his friends. He responded by introducing a new kind of leather whip for tops and by starting a rage for "suckers" which picked up cobblestones on a string. Next he popularized a blowgun, using bits of raw potato for ammunition, and followed that with other ingenious troublemakers. Soon his cronies were dropping in regularly after school to see what fresh devilry might be learned. George Stuart cried for mercy and begged Elihu to change to constructive experiment.

Young Thomson took the hint. There was an iron foundry near by, and he resolved to go there and learn to make castings of his own. But from the first the project was disappointing. Iron would not melt on the kitchen stove, nor in a miniature cupola he made from a tin can. A much larger furnace also failed until he gave



A replica of the famous wine-bottle machine for the generation of electricity which was one product of Elihu Thomson's freedom

J. Colin Forbes's portrait of Mary Ann Rhodes Thomson, the wise and understanding mother of Elihu Thomson

up iron and charged it with type metal picked up in a vacant lot. This melted perfectly. After much experimenting with patterns and molds, he finally achieved a perfect casting — a fairly good imitation of a jackstone. Elated, he began turning them out in quantity, till he made them well enough to sell to his friends.

But Elihu's ambitions were high. He meant to cast a cylinder for a real steam engine. It must be of iron; the only way to get the necessary high temperature was to fit his furnace with an air-blast fan. Copying diligently from the foundry, he built a fan out of a round collar box, with a wooden shaft carrying blades of sheet iron. The driving pulley was a spool, and the power wheel a cheesebox cover coaxed from the corner grocer. Another spool made the crank, and the two wheels were belted together with string.

The blower worked well, and Elihu hastened to charge his furnace with bits of iron and coke. This done, he lighted it up and began to crank with all his might. After a time he was rewarded with a thin stream of molten iron trickling out onto the kitchen floor. But success was short-lived. The mold which he had made for the engine cylinder was too large for the furnace. The iron cooled long before the casting could be finished. This disappointment was heartbreaking, but young Thomson took it in his stride. He realized that foundry work on this tiny scale was impossible and resolved to waste no more time on it. For the sake of rounding out the job, he carefully filled the furnace with type metal and fashioned a beautiful but useless steam engine cylinder. Then he turned his mind to something else.

Despite its failure, the experiment had been valuable. It had been Elihu's first venture into research. He had learned how to test an idea by actual trial and evaluate the results. More important still, he had demonstrated his good judgment in refusing to continue up a blind alley, once discovered.

From the beginning of his "vacation," Elihu had been reading every scrap of scientific material that came within reach. The most absorbing thing was an English monthly which his father received, called the *Imperial Journal of Art, Science, Mechanics, and Engineering.* Here he found a series of articles on photography. At once his great ambition was to build a camera of his own. Tackling the lens first, he attempted to cast it in his miniature blast furnace out of chips from glass bottles. Once the shape was achieved, he planned to grind and polish it according to the directions in the *Imperial Journal.* But before he reached this point, he made a discovery. While breaking up a glass doorknob one day, he found that some of the fragments themselves had the power to magnify. Elihu immediately set to work with a pair of pliers, snipping off the irregularities to make the little lens round. This done, he mounted it in a wooden handle and produced a fair magnifying glass.

The camera was forgotten. Soon Elihu was turning out magnifiers by the dozen and selling them for two cents apiece. Then he discovered behind a drugstore a pile of broken bottles whose round bottoms made even better lenses. Before long, Thomson's optical invention was such a rage in his former school that Stuart again had to beg the boy to take up other research.

The Civil War soon cut off the *Imperial Journal* entirely. Elihu was brokenhearted and begged his mother to buy him a book on photography so that he could complete his camera. Mrs. Thomson searched high and low, only to be told that no book existed on this new art. Unwilling to go home empty handed, she bought the *Magician's Own Book*, hoping that Elihu's interest could be diverted to sleight of hand. But he was not to be consoled. Then one day, leafing through the disappointing volume, he found himself suddenly in a new world. This was no mere collection of parlor tricks but a whole encyclopedia of natural science. After a few chapters of magic came hundreds of pages of experiments with chemistry, electricity, magnetism, light, and sound. There was a picture on every page, showing how the apparatus could be made and used at home.*

By sheer good luck, Mrs. Thomson had put her hands on a complete elementary text on physics and chemistry — the ideal handbook for the home laboratory of a boy of 12. It explained combustion and the making of chemical compounds such as laughing gas; it told everything known of electricity and magnetism, and illustrated various machines that could be built to demonstrate them; it considered pneumatics, aerostatics, optics, mechanics, hydraulics, and acoustics; and it ended with a treatise on geometry and numbers and a section of "Practical Puzzles and Paradoxes."

The *Magician's Own Book* was a turning point in Elihu's life, for it gathered all his creative yearnings into constructive channels and offered him real scientific knowledge. All day long he was buried in its pages, learning most of them by (*Continued on page 500*)

* The *Magician's Own Book*, published anonymously by Dick and Fitzgerald in Boston in 1857, is worth examining today. Few modern books for boys can match it for lucidity and completeness.

Community Endocrines

Harmony among Controlling Groups Essential to Strength in Public Affairs As in Life of the Body

By John W. M. Bunker

COMMENCEMENT ADDRESS

THE history of life upon this planet as written in the record of the rocks tells the story of the rise, the dominance, and the disappearance of dinosaurs and dynasties. They failed because they did not adjust themselves to changing environments. It is a recognized biological principle that a plant or an animal persists and maintains its integrity only in proportion to the success with which it makes the adjustments necessary to enable it to fit its surroundings. This is the phenomenon of adaptation.

Certain instances of adaptation are obvious; others are more subtle and inconspicuous. A certain worm that feeds upon chestnuts has the problem of getting by the spiny armor of the chestnut burr; hence the worm has developed an elongated snout. The arboreal apes have prehensile tails. Land animals have sweat glands that provide an adjustment to changes of temperature, which occur over the earth with greater amplitude than in the waters, whose denizens cannot and do not need to perspire. The increased sensory adaptability of the human being who has lost his sight is an example of adaptation. Charles Darwin cited the case of the New Zealand species of parrot which, after the introduction of sheep raising into its environment and after getting in some way a taste of blood, changed from a peaceful vegetarian species into a destructive, bloodthirsty carnivore.

The local environment of the Institute has changed in unexpected and erratic ways during the past year, requiring adaptations of a high order of complexity. Orderliness has invaded the dormitories. Student populations have been evacuated therefrom, upon sudden notice of military necessity. Pedagogical and other problems have arisen to test the whole Technology population, students and staff alike.

The mechanisms of adaptation in vertebrates, of which man is a specimen, comprise a system of detection, communication, selection of possible responses, and final effector action. The detection of stimuli from outside the body is by means of sense receptors — cells or associations of cells attuned to special resonance with incoming disturbances of particular periodicities and amplitudes; thus the eye to see, the ear to hear, the tongue to taste, the tactile sense, and the thermal detectors of heat gain or heat loss and of the rate thereof. These exteroceptors are bombarded with impacts from without, impacts which impinge alike upon tissues unresponsive and receptive. As with the radio receiver which has been left untuned, broadcasts are of no avail to the nonreceptive tissues; only the tuned receivers are functional.

Responses to the inciting impulses, or stimuli, are determined not by the nature of the stimuli but by the fundamental character of the organism which receives them. For this determination to be made by the receiving organism, there must be a mechanism of selection or choice. In man this mechanism resides of course in the intelligence, of which the physical seat is the brain. Therefore, from skin to brain must be a communication system, the nerves — conducting fibers which are spun into strands, combined into cables, and finally run together in the conduit of the spinal column to the switchboard of the brain.

Man chooses how he shall react. In his infancy he stumbles and falls; and according to his state of health, according to what he has observed others to do in like circumstances, and, not least of all, according to what he thinks others regard as the proper thing to do, he howls with whipped-up anguish or he gurgles with glee. As he enters young manhood, there comes a day when, as he strolls garbed in whites on a social errand, a truck swoops through a mud puddle and splashes his splendor. Does he get mad? Probably. According to the stories, Marcus Aurelius in a like situation would have consoled himself with the reflection, "There is one joy-riding aedile whose chariot missed me," and in due course would have donned a new toga. It was that same Roman philosopher who pointed out that an insult is not conveyed by the utterance of another but is created in the mind of the recipient if he so chooses.

Man, then, can choose his responses. His reply to threat may be appeasement or combat; to calls for help he may pharisaically assume the scaly shell of indifference or, like the good Samaritan, may lend a hand. And whichever way he reacts, his fellow men, hearing about his behavior, will pass judgment upon him.

The response having been selected, communications again are invoked and efferent nerve impulses bring about appropriate effector action. In time, responses become cast to certain patterns, and the automatic switchboard of the cerebellum takes over the routing of the reply to situations which become repetitious. The pilot, for instance, maintains flight upon an even course or, with speed quicker than thought, goes into sudden maneuvers which save his plane. In the social environment man's relations with man depend upon the types of adaptations to which he has trained himself, upon the habits which he forms in the beginning or which he later changes for good and sufficient reasons. Thus character is expressed in daily actions and reactions — on the one hand, suggestive of tolerance and consideration; on the other, of arrogance and greed.

The outlook of man upon existence and therefore his behavior are colored by his physiological health. We recognize disease, a state of unhealth which has patent symptoms, and we know that disease is not conducive to optimism. The bounding health of childhood is associated with exuberance in the joy of living. It is well known that our feelings influence our actions. That which governs health, therefore, controls to a definite degree the selection of adaptive responses. The brain is the governing agent of behavior, but the brain in turn is subject to inconspicuous yet effective direction. The animal body maintains its integrity as a healthful entity only if the appropriate balance of glandular secretions be preserved in the blood stream.

Certain glands have on occasion been styled as the glands regulating personality. Saying so is inflating metaphor into hyperbole, perhaps, but it is a fact that completeness of living physiologically depends upon what we call an equipotential endocrine balance. Certain glands of the body, not over a dozen in number, each a community of cells drawing upon the common supply of earthy chemical elements circulating in the body, select from these elements and by recombination turn out particular products of chemical compounds which, acting here and there in proper balance, keep the vital organs in a state of health and normalcy. A body in which the endocrine balance is not maintained cannot be in complete health. Brain activity reflects this imperfection, and adaptive responses lose their efficiency.

The life of the body, then, is not directed by its government or by its component individual cells but, rather, by the products of controlling groups of cells, part and parcel of the total population, small in number but great in importance.

In the body politic are analogous groups of men who, associated in kindred interests, skills, and occupations, by their concerted activities influence government and hence the behavior of the community. The church constitutes such a community endocrine factor; the press is another; art, literature, and philosophy have their adherents whose opinions and output surely help to stamp a civilization; scientists and engineers constitute a group of tremendous potential power; employers and labor are other groups. The body politic will grow in strength as these groups act in concert with consideration and understanding for each other's interests and ideals. Working together in harmony, they constitute the force which conditions their government and determines the relations of their community with others.

How the endocrines of the body maintain their balance, each in respect to all others, is a mystery of life beyond our comprehension. We do know that certain excesses of one bring forth counteractivities of another; we do know that the very presence of opposing tendencies in the body makes possible the exquisitely proportioned variations in over-all effect whereby the delicate balance of physiological fitness is maintained.

But in the human counterpart to these regulating associations of the units of body structure, it is possible to reason certain ways in which analogous balances may be secured. Misunderstandings are the bases of dissension. Misunderstandings are the results of misinformation or lack of information. Contention loses its acrimony and is often dissolved when, face to face, contenders define those matters about which controversy has arisen. Conflicts spring up more readily among strangers than among friends. Communication of ideas and wide sharing of thoughts are a powerful prophylaxis against dissension. Isolation is not the attitude which avoids war.

WHAT are some of the things which scientists and engineers, the group in which you and I share membership, can guard against and what are some of the things we can cultivate so that we may contribute to the balance that is needed in human relations?

One of the chief things we must guard against is the danger of carrying into our professional lives an overemphasis on specialization, which some think is a characteristic of present-day scientific and engineering education. The wealth of fact and art spread before the scientist and the engineer is so great that no man can encompass it all. In athletics, only the few are sufficiently proficient in 10 branches of sport as to be serious contenders in the decathlon; most champions are specialists. When a triple winner arises in a meet, it is a matter of headlines in the news. Likewise in engineering and science, selection of one field or another is the effective method for technological coaching and learning.

Fortunately, advances in natural science have broken down the barriers which terminology had erected between physics, chemistry, biology, geology, and so on. These names are now accepted as designating centers of interest in a broad range of scientific findings. No boundaries exist between these sections of science. Their respective fields are unfenced; one merges into adjacent areas as the grass on suburban lawns. When my neighbor pulls out his dandelions, his action improves my own greensward next spring; and if I ever find out how to eradicate crab grass, I shall promptly tell all my friends.

If unchecked, however, specialization in a profession may lead to exclusion of interest in nonprofessional fields. That result is undesirable. For without information, there cannot be understanding. A metallurgist once used this figure of speech in an address: On the roof of a high building, a group of graybeards were shooting arrows into the air. The metallurgist looked up and espied a cloud from which depended a pair of dangling legs. "Who is that you are shooting at and who are you anyway?" he inquired. To which one toothless gaffer replied, "We are chemists. That feller up there is a physicist; he has his head in the clouds and his feet a long way off the ground." Note that in this fable the archers were not young men.

There is but one way to understand the other fellow — that is to get acquainted. One way to get acquainted is to resort to the good old custom of calling upon our neighbors. See what they are doing; listen to what they are interested to talk about; find out their aspirations. Then when they behave in ways peculiar to their own kind, their actions will be more understandable to us. Nothing equals personal observation as a means of gaining ungarbled information; conversation is more illuminating than literature, though reading has its value. (*Concluded on page 506*)

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

Corporation Elections

J. WILLARD HAYDEN, President of the Charles Hayden Foundation and a brother of the late Charles Hayden, '90, was elected a life member of the Institute Corporation on May 28. Elected alumni term members for five years were Francis A. Barrett, '24, Walter J. Beadle, '17, and Donald F. Carpenter, '22. Irving W. Wilson, '11, was elected as an alumni member to fill the uncompleted term of the late Alfred H. Schoellkopf, '15.

Mr. Hayden was born in 1874, the son of Josiah W. and Emma A. Hayden, and was educated in the public schools of Boston. He was long associated with the firm of Hayden, Stone and Company, of which his brother was the founder, and he became president of the Charles Hayden Foundation in 1937. Mr. Hayden is a director of the Eastern Steamship Company, the Equitable Trust Company, and the Eastern Massachusetts Street Railway Company. During World War I, he was director of demobilization for the Young Men's Christian Association. His clubs are the Algonquin, University, Corinthian Yacht, and the Havana Yacht and Country.

William H. Bovey, 1871–1943

WILLIAM HOWARD BOVEY, '94, a life member of the Institute's Corporation since June, 1924, died in Edina, Minn., on April 26. Mr. Bovey, who was 72 years old, was widely known in the milling industry of the Middle West. Associated with the Washburn-Crosby Milling Company for 33 years, he held the post of vice-president in charge of milling operations upon his retirement in 1928, when his firm became a division of General Mills. Since then he had been vice-president of the Cannon Valley Milling Company, of which his son, William H. Bovey, Jr., '22, is president.

In recent years Mr. Bovey spent much of his time in the direct application of his great interest in education and philanthropic projects. His concern for the welfare and progress of the Institute was indicated by his active participation in the affairs of the Corporation. In 1914 he became president of Dunwoody Industrial Institute and was associated with William H. Dunwoody in the development of this vocational training school. Relinquishing his post as president in 1937, he became chairman of the board of trustees. From 1913 to 1933, Mr. Bovey was a member of the Minneapolis Park Board and had served several terms as its president. He had also been a trustee of Carleton College and a director of the Carleton Corporation.

William H. Bovey, '94

The Review is not published during the summer months following July. This issue, therefore, concludes Volume 45. Number 1 of Volume 46 will be published on October 27 and dated November. Readers who bind their copies are reminded that if they possess nine issues of Volume 45, their files are complete. An index to the volume will be ready on August 15 and will be supplied post free upon request.

May Graduation

GRADUATION exercises for graduate and undergraduate students of the Institute who completed their academic work after the regular commencement last February were held in New England Mutual Hall, Boston, on the evening of May 28. Dean John W. M. Bunker delivered the commencement address.

A total of 279 degrees and 10 certificates of public health were awarded to 261 candidates. The distribution of degrees was as follows: doctor of philosophy, 16; doctor of science, 13; master in city planning, 2; master in public health, 9; master of science, 139, of which 28 included the degree of bachelor of science; bachelor in architecture, 1; and bachelor of science, 99. Among the graduates were 17 young women.

Athletes Acclaimed

THE 1942–1943 season for Institute track and crew athletes was one of the most successful in Technology annals. Oscar Hedlund's track team ended an undefeated

Presented by alumni of the Lowell Institute School, this clock in the lobby of the Rogers Building honors the memory of A. Lawrence Lowell, trustee of the Lowell Institute and life member of the Technology Corporation.

M.I.T. Photo

season, having won from Brown, Holy Cross, Boston College, and Tufts in two triangular meets. The scores were as follows: *First meet:* M.I.T., 68¾; Brown, 42; Holy Cross, 24¼. *Second meet:* M.I.T., 72; Boston College, 47⅓; Tufts, 45⅔.

The M.I.T. crew season this year included only two regattas: the first, a dual race with Harvard on the Charles in Cambridge on April 24; and the second, a five-crew regatta on the Severn in Annapolis on May 8. With less than three-quarters of a length separating the shells, the times for the Harvard-M.I.T. race were: Harvard, 6:59; M.I.T., 7:01.5. At Annapolis, M.I.T. finished second behind the Navy shell, defeating Princeton, Pennsylvania, and Columbia.

Our varsity crew was by far the best in recent years. Buck Walsh, Navy coach, paid the crew the compliment of calling it the best M.I.T. crew he had ever seen.

Finale

WINDING up another year of varied operations, the Alumni Council held its 233d meeting on May 24, the place being the University Club in Boston. Presiding in the absence of President Francis A. Barrett, '24, was Harold Bugbee, '20, Vice-president of the Alumni Association. Presentation of annual reports of the various officers, committees, and councils of the Association was the principal business of the meeting. Notwithstanding adjustments and alterations in usual practice which have been made necessary by the war, the reports indicated, the Council's work for the year as a whole has been effective, notably in its fostering of active support for the Institute by Alumni and in its seeking of further ways for the utilization of the energies of its members.

Speaker of the evening was Robert S. Harris, '28, Associate Professor of Biochemistry of Nutrition at the Institute, whose task was the giving of some answers to the question, "What Shall We Eat?" Increased per capita consumption of food; shipments of food to the armed forces for feeding the troops, for stock piles, and for feeding Allied troops; and Lend-Lease shipments, mainly of milk powder, egg powder, fats, soya, and cheeses, were cited by Professor Harris as the causes for present food shortages. Surveying the disposition of stocks of various primary foods, he did not find much basis for optimism about dietary prospects for the year ahead.

Problems of rehabilitating agriculture and livestock in Europe after the war were sketched by the speaker, who pointed out the great need for seeds that will be encountered, as well as the fact that few of the right strains for European cultivation are produced in this country. The need for farm machinery in Europe in order to make a rehabilitation program effective, Professor Harris argued, must be reckoned with as a manufacturing problem on this side of the water.

Messrs. President

TEN national professional scientific or engineering societies at present give evidence of the professional activity of M.I.T. Alumni. President of each of the groups in the following list is a Technology man: American Chemical Society, Per K. Frolich, '23; American Institute of Consulting Engineers, R. E. Bakenhus, '96; American Institute of Electrical Engineers, Harold S. Osborne, '08; American Society of Heating and Ventilating Engineers, Everett O. Eastwood, '02; American Society of Mechanical Engineers, Harold V. O. Coes, '06; American Society for Testing Materials, Herbert J. Ball, '06; American Society for X-Ray and Electron Diffraction, Martin J. Buerger, '24; American Standards Association, Rufus E. Zimmerman, '11; National Association of Food and Drug Officials, Hermann C. Lythgoe, '96; Society of Automotive Engineers, Mac Short, '26.

Planner Plus

The Review has pleasure in, on occasion, introducing its readers to outstanding women graduates of the Institute, and this is one of the occasions.

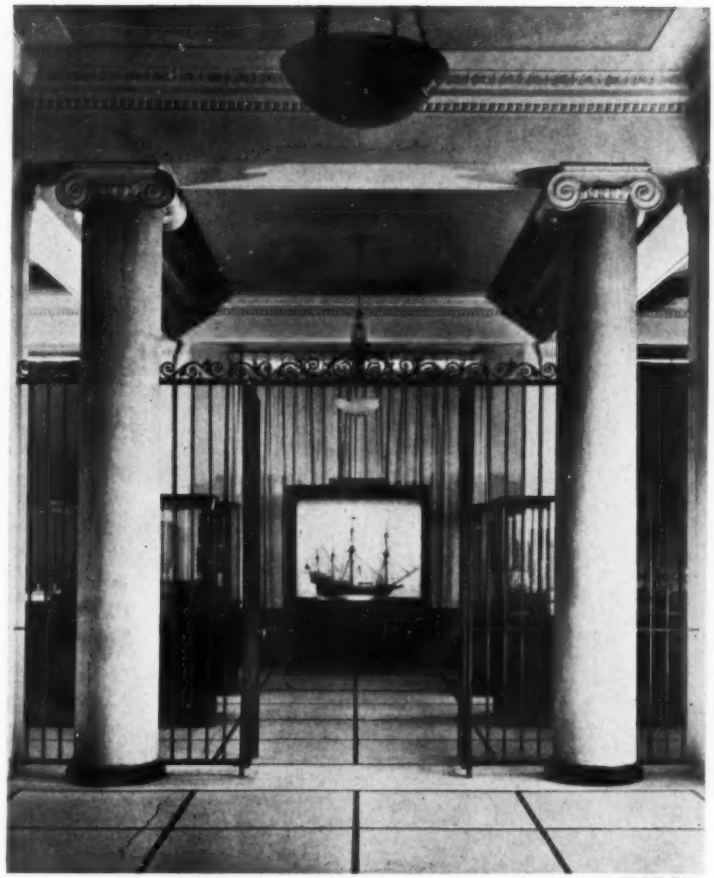
CITY PLANNER, author, wife, and mother, Flora Crockett Stephenson, '37, the first woman to be graduated in the Institute's Course in City Planning, is in England working side by side with her husband, Gordon Stephenson, '38, on important research on war building.

Mrs. Stephenson was born in New Jersey, a descendant of a seafaring family — of which she is very proud. She transferred from Mount Holyoke College to Technology, where she received the degree of bachelor of architecture in city planning in 1937 and a master's degree in city planning in 1940. In 1938 she married Gordon Stephenson, who had come from England on a fellowship to study in the School of Architecture. He received the degree of master in city planning in 1938.

On their wedding trip, the Stephensons drove to Mexico City to attend the 16th International Housing and Town Planning Congress. They wrote an interesting report of this congress for *Keystone*, the journal of the Association of Architects, Surveyors and Technical Assistants in England.

The names of Flora and Gordon Stephenson have appeared beneath the titles of articles in many English periodicals. They write not only about the architectural and city planning phases of camps and housing but also about the cultural and social aspects involved. For a special issue on camps of the *Architects' Journal* of July, 1939, they wrote a 16-page survey of recreation, school, and summer camps in eight countries.

The Housing Centre at 13 Suffolk Street, London, put on an exhibition of camps in March, 1939, under the direction of Mr. Stephenson. Mrs. Stephenson wrote an article on camp administration for the handbook published after the exhibition. In an accompanying flier appeared the following tribute: "The Housing Centre wishes to thank all those who have contributed material to the Exhibition and especially . . . Mrs. Gordon Stephenson for her invaluable help in preparing material for the Handbook and in many other ways. The important research she is making into the subject of camps has gone far to make possible the representative nature of the Exhibition."



M.I.T. Photo

Entrance to the Francis Russell Hart Nautical Museum

In 1942, the Stephensons made a survey for the Community Centres Joint Research Committee. They visited and studied camps all over the British Isles. As Mr. Stephenson was busy with war work, most of the material was assembled by Mrs. Stephenson. Their findings were published in an illustrated book entitled *Community Centres*. In this book, which is the first compilation of data on the subject, they give detailed descriptions of community centers, their architectural plans, their service to the community, and their position in a war world.

From the beginning of their married life, the Stephensons have been dogged by the horror of war. In September, 1938, they stepped off the boat into England — to be greeted by the necessity that they be measured for gas masks, as the Munich scare was in the air. They were in London during the early months of the war, and later went to Liverpool, where the bombing was so severe that Mrs. Stephenson went to North Wales. She stayed there until the British Government sent her with her husband to Staffordshire. They later returned to London.

A daughter, Gail Crockett, was born to the Stephensons on April 12, 1942, in Bebington, Cheshire. From all accounts she is a husky and healthy young lady, in spite of being a war baby.

At the present time, Flora Crockett Stephenson is trying to find time from her duties as a wife and mother to write a new book. Gordon Stephenson is working with the Ministry of Town and Country Planning on reconstruction plans for London. Highly successful in their chosen field, they are carrying on the Technology tradition of service.

Books for War

AMONG the hundred volumes selected by the American Institute of Graphic Arts to make up a traveling exhibit entitled "Technical Books for a Nation at War," a considerable number have especial Technology interest. Physical attractiveness, durability, suitability to purpose, and "the success with which the publisher had solved the various problems imposed by editorial content and conditions of production" were the standards of selection used in choosing books for the exhibit. The Institute's own Technology Press imprint appears on one of the volumes, *Electric Circuits*, issued through John Wiley and Sons, Inc. Following is a list of the volumes of particular M.I.T. significance:

Fighter Facts and Fallacies, by John G. Lee, '21, with introduction by Jerome C. Hunsaker, '12; William Morrow and Company, 1942.

Simplified Theory of Flight, by H. Erich Nietsch, '38, and Thomas C. Gillmer; D. Van Nostrand Company, Inc., 1941.

(*Concluded on page 514*)

THE SKILLFUL SKULL

(*Concluded from page 486*)

features of a system of arches with something of a spherical form, there would be a danger that blows delivered on top of the head might result in frequent fractures of the bones. This contingency, we have already pointed out, is partially met by the arches of the skull, the fact being well known that an arch is better able to resist stresses of this kind than is a sphere. In addition, the skull is made up of a fairly large number of independent bones, 22 in fact, which are joined to one another by means of denticulate processes that dovetail with those of the opposite bone and thus form the sutures of the skull. Until middle age, there is a certain amount of give, or tolerance, at these joints. The younger the person, the greater the amount of give. It is at these joints that the bones may take up the spread which may be caused by a sudden powerful blow on the head.

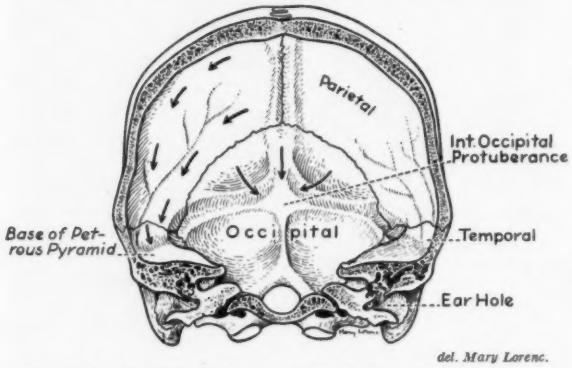


Fig. 8. Section through the top of the skull passing through the back of the earholes. Note how the features of the arch and the sphere are combined in its shape; how the petrous, or temporal, pyramid forms an enormous buttress which at the same time also serves to receive the forces traveling downward from the top and sides of the skull. Note the great sagittal arch in the middle of the skull and how it terminates at the internal occipital protuberance and then passes toward each side.

The fact has already been mentioned that the base of the skull is somewhat weakened by the number of foramina which pass through it as well as by the fissures which traverse it. This weakness would be very considerably greater but for the presence of a remarkable bone the architecture of which would alone require a treatise to describe. This is the temporal bone (Figs. 2, 3, and 8). It consists of a lateral portion and a pyramidal projection. The former fits like a shield, or scale, over the adjacent bones on the side of the skull, and its upper uneven border describes about two-thirds of a circle. The pyramidal projection extends forward toward the center of the skull and forms part of the base of the skull. It is so hard a bone that it is known as the petrous portion of the temporal. It houses the sensitive organs of hearing, the semicircular canals, and numerous important nerves and blood vessels. It is a very fortunate thing, therefore, that this portion of the temporal is so hard a bone, since it must be able to withstand every possible form of stress and strain. That it successfully does so is testified by the fact that of all the bones of the skull it is the one least frequently injured.

The form of the petrous bone is interesting: A four-sided pyramid arising at right angles from the squamosa or scale of the temporal bone, it lies upon its side with its apex pointing toward the body of the sphenoid bone and a good part resting against the basilar portion of the occipital bone. Two of the sides of the pyramid lie within the interior of the skull, and two lie outside it. Within the interior of the skull the hindmost side is perpendicular, whereas the other side is above this and more or less horizontal in position. The external sides are not so flat or smoothly surfaced as the internal ones, being rather roughened and somewhat excavated by grooves for the large vessels which lie in relation to them; but their positions are complementary to the internal ones. It would seem highly probable that a large number of the shocks received by the head on the top and side walls of the skull are transmitted through the squamous portions into the petrous portion of the temporal bone, which thus serves as yet another great shock absorber for a good part of the base of the skull.

From this brief, and unavoidably sketchy, account of some of the principles governing the architecture of the human skull, the reader will be able to judge for himself how alike are the fundamental principles which determine the relations among structures and the functions they subserve, both in the animate world of nature and in the world of artificial structures which man himself creates. It should be apparent that those principles are actually identical and that the more closely man approaches mastery and improvement of them, the more nearly perfect are structures he builds likely to be.

THE NEXT DECIMAL PLACE

(*Continued from page 482*)

himself become a special consultant to a branch of the War Department. At Brown University a strong graduate school of applied mathematics has been established. A considerable group of well-qualified young mathematicians came for training to a special intensive summer session conducted by this school, and its regular sessions have now presumably been established on a permanent basis. At the M.I.T. such Departments as Mechanical Engineering, Electrical Engineering, Aeronautical Engineering, Meteorology, and Geology have long had men of the highest research-engineering type, well versed in advanced mathematics; such men, together with representatives of the M.I.T. Mathematics Department itself, now form an interdepartmental committee to sponsor and develop applied mathematics. At New York University a smaller but excellent group is similarly emphasizing applied mathematics. In addition to these specialized groups, nearly all the former centers of pure mathematics are increasing work in the applied fields.

The whole atmosphere of mathematics in America thus is altering. It is a change that may be counted on to permeate the future of science and industry on this continent. The review made for the National Resources Planning Board in 1940 showed that, despite the enormous magnitude of American industry, it employed only about 150 mathematicians (not including statisticians and actuaries). Of the 150, one-third were in the elec-

(*Concluded on page 498*)

An air-minded world waits for wings

BECAUSE of the airplane, the peace to come can be as global as the war. Trade and transportation will move freely to peoples never before a part of the world's markets. Millions to whom modern life is unknown have already met and understood the airplane. Like all of us, they will welcome its cargoes.

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Today the copper industry is producing all-out for war. No copper is available for any other use. But post-war planners with specific problems in metals are referred directly to the Revere Executive Offices in New York.

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THE NEXT DECIMAL PLACE

(*Concluded from page 496*)

trical communications industries alone. Today, when refinement to one additional decimal point may mean the difference between a mediocre and a superior weapon, the demand for industrial mathematicians by the Office of Scientific Research and Development, the Navy Department, the War Department, the National Advisory Committee for Aeronautics, and the various laboratories and manufacturing plants which are producing the new weapons, is in excess of the number that the existing schools can supply. Indeed, the output of several additional schools of applied mathematics could easily be used in the war effort, but there are not teachers enough to man them.

The service of mathematics in war of course is not limited to assisting or guiding engineers in the design, production, and testing of a weapon. It extends to the use of the weapon, the organization and direction of the fighting resources, the participation in battle. At West Point and Annapolis, the courses for the training of cadets and midshipmen are founded on solid years of mathematics; the study of physics, chemistry, and other technological subjects is strongly mathematized; and these subjects are not elective.

In contrast with this long tradition of rigorous training in analytical and objective habits of thinking at West Point and Annapolis, most of the American universities and liberal arts colleges have gradually broadened their requirements, making mathematics an elective subject, so that in consequence undergraduate interest in it sagged to a new low. Only a handful of students took any mathematics in college, and many of the high schools and preparatory academies reduced their mathematical requirements to a very elementary level. In 1942 a prominent industrial research director said that even the boy who finishes high school with an "A" grade in mathematics has a poor foundation on which to build his future work in science.

These deficiencies in our educational system have been a serious handicap in the present emergency. The wartime Army and Navy, confronted with the problem of recruiting large numbers of men as future officer material, found ignorance of mathematics one of the most serious bottlenecks. From his experience as chief of the Navy's Bureau of Navigation in 1941, Admiral Chester W. Nimitz reported that 4,200 freshmen in 27 leading colleges were examined for admission to the Naval Reserve Officers' Training Corps and that 68 per cent failed to pass the entrance test in arithmetical reasoning. Only 10 per cent had studied elementary trigonometry, only 23 per cent had taken more than a year and a half of any mathematics in high school. When it came to college graduates — men who had successfully completed their four years — of 8,000 who were considered for commissions as ensigns, 3,000 had to be rejected because they were woefully deficient in mathematics.

Army engineers report much the same conditions. Sifting young men for the highly technical and specialized services of the Corps of Engineers, the Signal Corps, the Air Forces, and the Artillery, they found that a large proportion of the recruits were unfamiliar with geometric relations and many were unable to perform simple arithmetical computations. In one Coast Artillery regiment, arithmetic was so foreign to the capacities of most of the men that the entire group had to be put through months of instruction. Aviation in particular calls for a firm groundwork in elementary mathematics by pilots, navigators, and bombardiers; they must be proficient in arithmetic and geometry, and must also have some grasp of physics and trigonometry. With crews averaging three men per plane and with aircraft being produced on the scale of 100,000 a year, the training courses must care for several hundred thousand men a year for the air arm alone — while other mechanized branches of the Army are demanding equal or corresponding mathematical training for their personnel.

The high-school and college curricula have been made over on a nation-wide scale to meet these needs of the Army and Navy, and mathematics is resuming its historic place in education. Whether this trend will continue as a postwar policy, one can only conjecture. But, at any rate, many hundreds of thousands of young Americans will have been introduced to a scientific tool of great usefulness and to a method of thinking which cannot fail of influence on their lives in peace as well as in war.

While the Army and Navy, through their contractual arrangements with selected colleges, are thus training military and naval recruits, hundreds of other institutions have made shifts in their teaching arrangements. These are designed to provide training for young civilians in order to prepare them for service in war industries, laboratories, arsenals, ordnance works, navy yards, and other places where mathematical knowledge is essential to efficient production. At the close of 1942, for example, Brooklyn College in New York had 4,000 students studying mathematics — 3,000 in day courses and 1,000 in night courses, with an increasing proportion of young women in the classes. The program here is typical of the intensive acceleration of teaching in scores of institutions, particularly municipal colleges and colleges in large population centers.

The return to mathematics has educational significance in that the teaching of mathematics can be harnessed to practical problems. Instead of taking up mathematics as recent college graduates have — as an enforced exercise in mental gymnastics, a cultural something necessary to fulfill the requirements of the law and win a college degree — young people of today approach the subject as a tool to be used. Newton invented the calculus because he needed a tool with which to describe the path of a moving body whose velocity was changing at a fixed rate, a very real problem with which he was wrestling at the time. Similarly vector analysis had its origin in the need for a tool with which to attack a particular problem in mechanics. When taught the calculus and vector analysis as tools to be used in making and using guns, aircraft, submarine detectors, and warships, students partake of some of the satisfaction of the inventors who devised these powerful techniques. A beautiful thing loses none of its beauty and none of its importance by being found useful, and at the same time it becomes more interesting, more comprehensible, and more acceptable. Therein lies a promise of possible permanence for our mathematical renaissance.

Don't laugh— *the world gasped*

When the alarm sounded, there was much excitement, but no confusion. The stall barriers dropped automatically, the trained horses leaped to their posts and the harness dropped into place from above. Steam was always up and, as the engines rolled out, a flare on the floor touched off the shavings and kindling in the firebox. Because they were so efficient and so simple, American fire departments became the models for the rest of the world.

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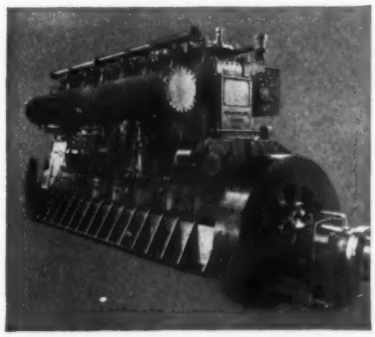

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FIRST VOYAGE

(*Continued from page 490*)

heart. In later life he repeatedly fell back upon this splendid course of training in demonstrating to others. All the fascinating exhibitions of parlor magic with which he thrilled every child who knew him originated in this extraordinary book.

By this lucky turn of fate was Elihu Thomson's scientific career begun. A special providence apparently brought him the right influence at the critical moment, as it had done with Faraday, Henry, and Edison. Genius, it seems, is the special concern of heaven through the medium of inspiration from a book. For example, Joseph Henry at 13 was an apprenticed watchmaker, a trade he detested and planned to abandon for the stage. One day he chanced to pick up a book called *Lectures on Experimental Philosophy*, which a boarder at his grandmother's house had left open in the parlor. He began to read it casually but was soon so enthralled that he determined to make science his career. Eagerly he took courses in natural philosophy at the Albany Academy, was graduated with high honors, and became its professor of chemistry. He was soon a world celebrity.

Faraday's inspiration was remarkably similar. At 14, he was apprenticed to a London printer and had to do the bookbinding for the establishment. He disliked this as much as Henry did watchmaking. Finally an encyclopedia came in to be bound, and Faraday chanced to read its few paragraphs on electricity. His future suddenly became clear. He began attending the public lectures on chemistry which Sir Humphry Davy was giving at the Royal Institution, and he made such excellent notes on the discourses that Davy hired him as his private assistant. In a few years Faraday had become a greater scientist than Davy himself.

Elihu Thomson at 12 determined to make "experimental philosophy" his profession. At first electricity interested him beyond all else. Its mysterious actions offered endless possibilities for original discovery. In the *Magician's Own Book* he found an article on how to make a friction machine to generate electricity. "It is very easy to make a glass machine of the cylindrical form if the maker cannot afford to buy one . . . ," the article explained. These were magic words to a boy with skillful hands and an inventive mind! All that one needed was a wine bottle, a spindle and crank, a leather pad, and a piece of silk. The article assured the young reader that the machine, once made, would do a host of experiments with sparks, among them "the electric kiss," "imitation thunderclouds," and "how to draw sparks from the tip of the nose."

For several days Elihu was occupied with the difficult business of boring a square hole through the bottom of a wine bottle, then mounting the bottle on a shaft to revolve smoothly against a leather pad when a crank was turned. His familiarity with glass soon solved this problem and other smaller ones, and the homemade friction machine was ready. With the first turns of the

(*Continued on page 502*)

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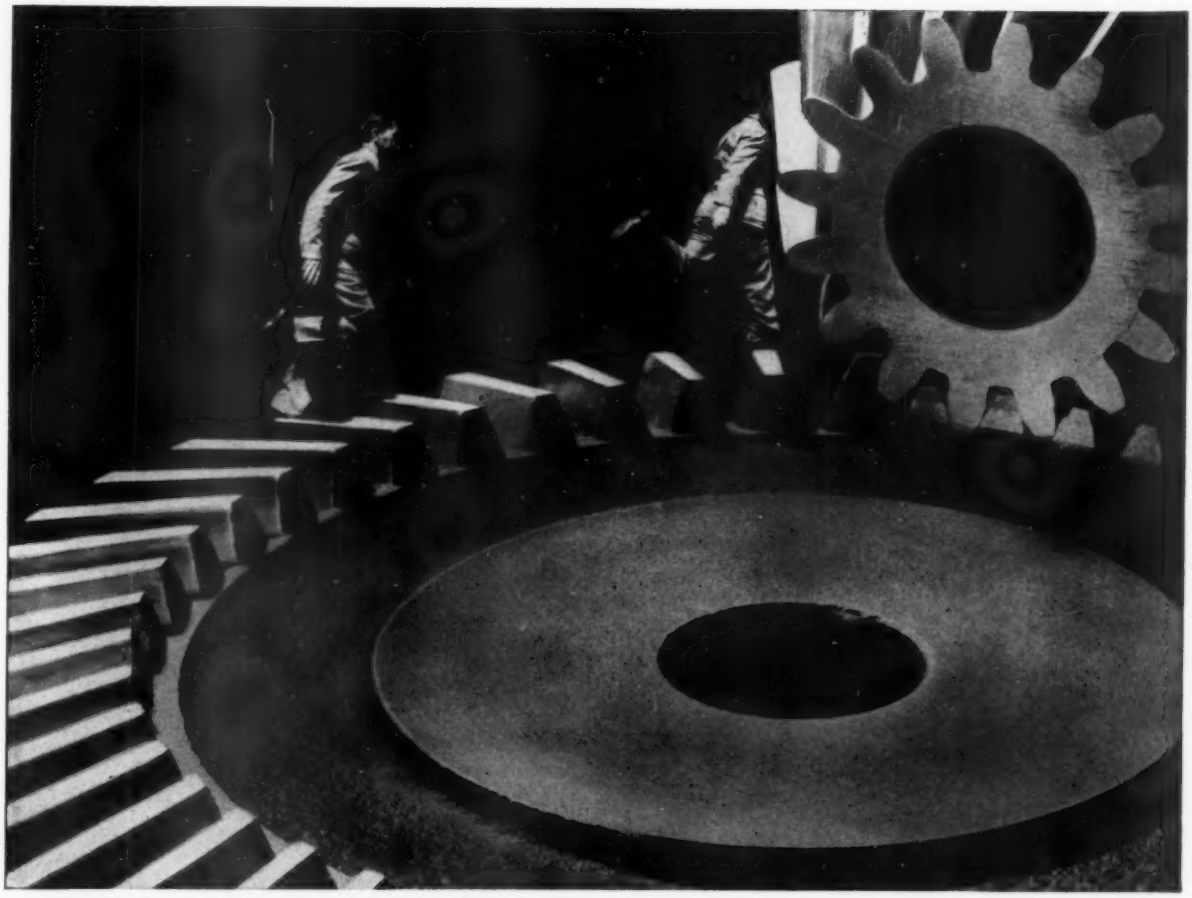

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FIRST VOYAGE

(*Continued from page 500*)

shaft of his apparatus, the young scientist was rewarded with a beautiful spark almost half an inch in length. He next followed instructions for building a small Leyden jar and learned that the book was inaccurate in suggesting that all glass has good insulating qualities. Fruit jars of a pink color would not hold electric charges at all. He decided that the iron salts in the glass were to blame, and took care thereafter to use only jars of pure white.

Soon after the outfit was ready, Elihu's father returned from a business trip to Cuba and asked what his son had been doing with his time. The boy fetched his friction machine and exhibited it proudly. But Daniel Thomson was not impressed. He did not believe in praising his children if it could be avoided. Elihu gave the crank a few quick turns and invited his father to grasp the terminals. Thomson did so, smiling. The feeble discharge made scarcely any impression on his tough machinist's hands. He brushed the whole experiment aside as unworthy.

The young experimenter returned to his bedroom workshop, determined to find a way to give his father a real electric shock. If one Leyden jar would not do it, he must build a whole battery of them. But without the tin foil necessary to make them he was forced to invent a substitute. He tried immersing a number of jars in a big bowl of water and partially filling them with it also. To his delight the scheme worked perfectly; the sparks from the machine were fat and bright and gave promise of saving his reputation.

One snapping cold winter night he set the stage for his comeback. "I cranked the electric bottle machine hundreds of times and got a real charge in my battery," he wrote gleefully, years later. "Then, most innocently, I requested my father to attend the experiment and complete the circuit. He did so readily, believing that this time he would put an end to my foolishness."

What happened frightened even Elihu. The shock threw Daniel Thomson into the air and landed him on his back, where he lay cursing till his wife ran in and picked him up. On his feet again, he stood glowering at the machine, rubbing his benumbed arms. The boy waited silently. This was surely the end of his home laboratory. Then his father held out his hand and enthusiastically gave Elihu his approval. From that moment on, the boy's place as the scientist of the household was secure.

From the *Magician's Own Book*, Elihu next learned how a telegraph was made and how to set up the galvanic battery to run it. This led him to experiment with the innumerable mysteries of chemistry and physics that crowd the everyday world. Trying them all, he mastered the known fundamentals of the physical world. There were no limits to his experiments except those of his own skill and patience. The dangerous forces he might release depended solely on his own judgment and natural caution. He was already too well informed to risk his life, but he got splendid training in invention from the constant necessity of finding and adapting his

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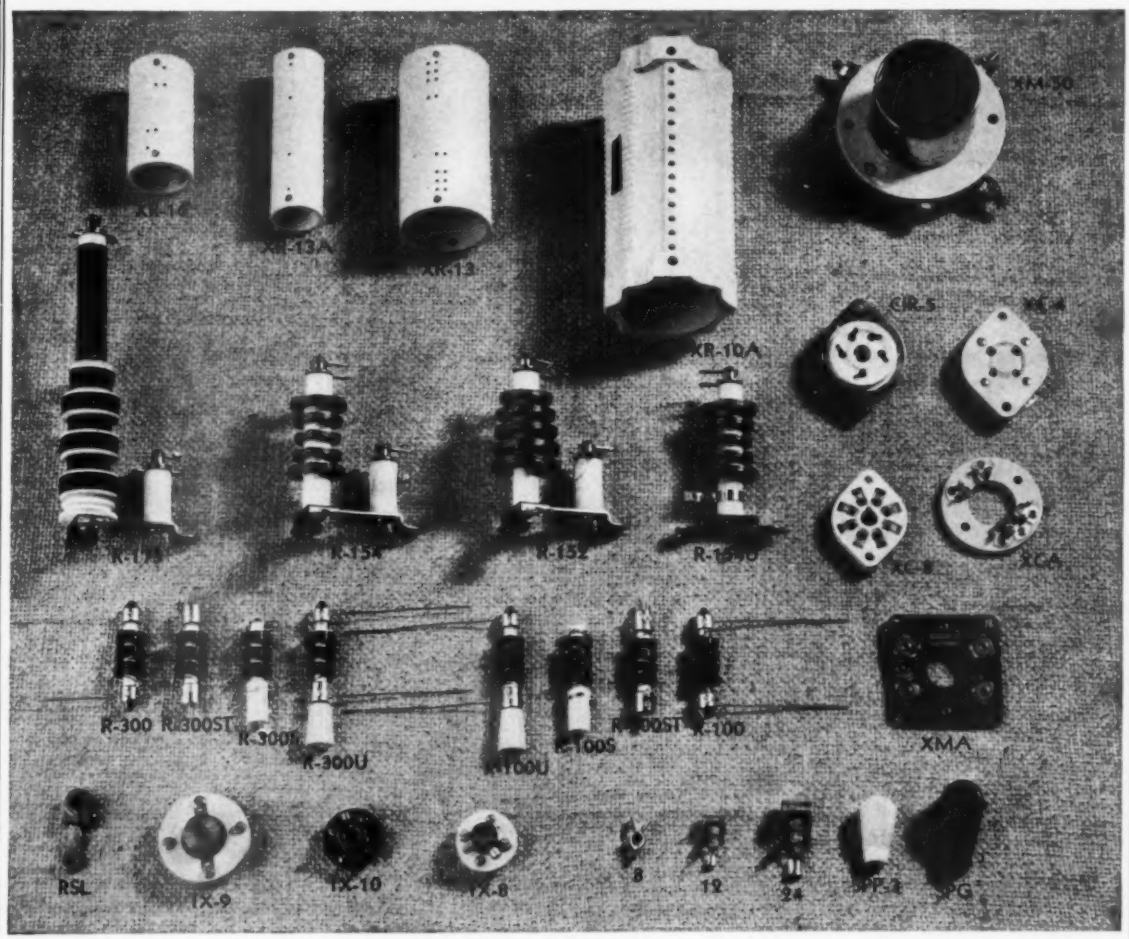

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FIRST VOYAGE

(*Concluded from page 502*)

own materials. His complete lack of money to buy what he needed was a great aid in his developing and understanding the potentialities of everything he used.

Thus the fashioning of a bent nail to make a pair of electromagnets was not a serious problem, but the insulated wire for winding the coils upon them taxed his ingenuity to the utmost. Out of his own head he devised a way of winding cotton thread on the bare wire, and so repeated an important invention which Joseph Henry had made at Princeton College many years before. The magnets were presently forgotten, but the knowledge of insulation remained to help the boy later when he built his first dynamo.

When the telegraph was duly successful, Elihu's interest in experimental laboratory work temporarily abated. Now he turned to sleight of hand and ventriloquism, mastered them, and then spent a short interval trying to educate a parrot his father had brought home from Puerto Rico. When the bird refused to learn the multiplication table, the boy took to the mechanical arts. With his father's help, he got permission to hang around the Philadelphia Navy Yard, not far off. There were fascinating things going on there, among them the building of the *Tonawanda*, the first battleship-of-the-line of the United States Navy to be armored with iron, and one of the first driven by Ericsson's screw propeller.

The yard was seriously shorthanded. After a good deal of pleading, Elihu got the job of running for an hour each noon the donkey engine which was finishing the hole for the propeller shaft in the battleship's sternpost. He was a proud and happy boy to feel that he had so important a part in fighting for the Union. For weeks he spent all his time there, watching every operation of shipbuilding, especially the installation of the great slabs of armor plate along the *Tonawanda*'s water line.

At length, in the fall of 1865 at the age of 12½, Elihu went back to grammar school to repeat his examinations for Central High. George Stuart welcomed him with delight. He had moved to a school two miles away but insisted that Elihu follow him there. He wanted to put the last loving touches to the boy's primary education himself. Gladly Elihu made the daily four-mile walk and often went in the evening to the schoolmaster's house, where they discussed his future in every detail. Elihu told him he was sure now that he wanted to be a scientist.

One day Stuart kept him after school, and when the building was quiet took him to a big cabinet whose glass doors were always locked. Elihu had stared through those doors many times at the wonderful array of apparatus within — friction machines, electromagnets, galvanometers, and all the rest. Now George Stuart unlocked the doors and lifted the treasures out, one by one. And they stayed into the night to experiment, to question, to remember, tramping happily side by side with the scientists of the shadowy past.

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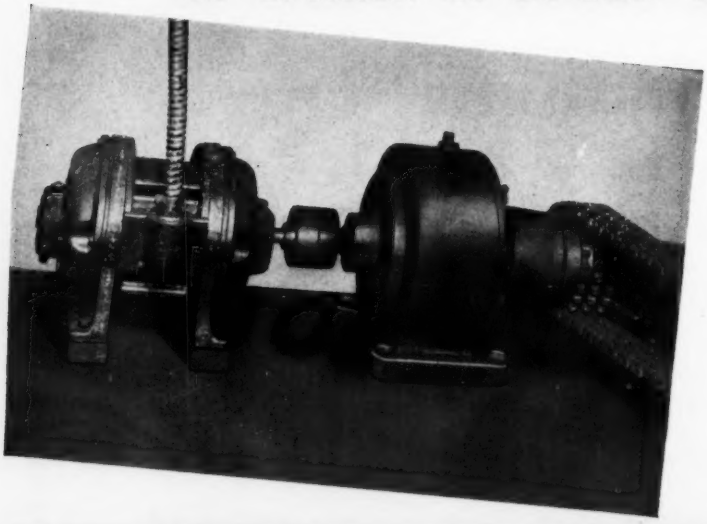

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(*Concluded from page 492*)

We take for granted the printed word and can hardly realize what an invaluable aid to human progress the art of the book has been. Since printing was invented, fewer rediscoveries have been made. Previous to the Fifteenth Century, many a stimulating concept regarding the nature of the universe had been formulated, only to become lost through lack of permanent records. Pythagoras perceived that the earth moved around the sun, but few took him seriously, and because of lack of publication his thesis was forgotten. Ptolemy, 600 years later, with an eye perhaps to the powers-that-be of his time, took the opposite stand and got away with it. When Copernicus, more than a thousand years thereafter, backed up Pythagoras and, moreover, put his theories into a book — which he was able to do thanks to the achievements of Gutenberg — the record was fixed for all time.

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And in respect to travel, one may recall the fairy tale from which Horace Walpole quoted in a letter to a colleague in 1754. It is the story of the three princes of Serendip, who "as they travelled, . . . were always making discoveries, by accidents and sagacity, of things which they were not in quest of: for instance, one of them discovered that a mule blind of the right eye had travelled the same road lately, because the grass was eaten only on the left side, where it was worse than on the right. . . ."

In this suggested quality of serendipity, then, we have a key to successful exploration and research, whether in peace or in war, in natural science or in social science, in government or in economics. With receptors alert to receive and the mind open to interpret, the way is opened to knowledge.

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Liquid

BARNUM BEGAN IT

(*Continued from page 488*)

Though the attendance at many New York museums has dropped off in varying degrees during the war years, that of the Museum of Science and Industry has forged ahead 15 per cent as between 1941 and 1942. The Museum of Modern Art in New York City has also shown increased attendance, and again we find that a studied and persistent effort has been made to offer special exhibits, principally of war interest. (Incidentally, both the Museum of Science and Industry and the Museum of Modern Art charge an admission fee, whereas other museums of large attendance in New York City do not.) Though statistics regarding museum attendance are as difficult of analysis as any other sets of statistics, still it is perfectly apparent that the special exhibit, with its "newness" and its ability to answer a question, is an important factor.

The experience of the Boston Museum of Fine Arts during the war years is interesting and to the point: Attendance rose from slightly over 400,000 in 1938 and 1939 to 513,000 in 1941 and 546,000 in 1942. The authorities at this museum likewise attribute the increase to special exhibits, stressing highly successful showings of the Thorne miniature rooms in 1941 and 1942.

The arrival of peace, then, should find the museum well prepared, through its new outlook and its technical experimentation, to tell a dynamic story to a still-puzzled but jubilant and vitally interested public. If the opportunity is seized in time, before any reaction sets in, the museums may very likely capture a dominant place in the spreading of culture throughout our land — not culture in the academic sense but rather in the sense of understanding and feeling the mighty changes that have come over the world as well as those that are in the making. To exhibit the law of compensation actually functioning — that is a challenge. As, through applied science, there will never before have been such great destruction, so, through the same force, there will never before have been such great opportunity to rebuild well and wisely.

This challenge is no idle one. In McKinley's day, we heard the slogan of the "full dinner-pail," an appeal to the biochemical; in the 1920's, it was "two cars in every garage," an appeal to physical comfort. The signs point to something new, something better — and that is knowledge, or culture, a broader, richer horizon.

In speaking of "culture," one should distinguish between the meaning which refers to the daily life, the techniques, and the arts of a people and the meaning which refers to a cultivation and training of the mind, leading to an appreciation of all that is good in human endeavor and achievement. In the latter sense, the word is apt to be used in too limited a fashion, pointing merely to a self-centered, unworldly type of learning; this is an unfortunate tendency, for the culture of the mind, if the term is to retain anything of its former significance, implies breadth, completeness, and vitality.

If one looks back to what the word "culture" meant to the educated gentlemen of the Renaissance, one is reassured. For though they delved deep into the lore of

(*Concluded on page 510*)

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BARNUM BEGAN IT

(*Concluded from page 508*)

antiquity and revived the thinking in the Greek and Latin manuscripts, they did so with a worldly purpose. The past was not dead to them; it was alive, very much alive, and it had a limitless value to all who should read. No doubt Hero of Alexandria, antiquity's first-rank gadgeteer, inspired Leonardo when the latter was designing "secret weapons" for his princely patron's army and was studying the bird's wing in an effort to work out theories of aerodynamics. Ptolemy the geographer, dead more than a thousand years, gave heart to Columbus and challenged Copernicus to produce something better. Vitruvius of Rome was studied not for his own sake but for practical ideas on architecture and building construction which could be used for the then modern palaces and cathedrals. Culture to the Renaissance was a bootstrap. It was a living force, open to all, used for all.

We have heard much in the immediate past about the great danger that the leveling effect of democracy is downward and that culture suffers thereby. We have heard much, too, about the danger that the mechanical side of the age has a similar lowering effect. It is also frequently said that no broad, synthetic understanding can exist in the present advanced state of our civilization, with all its complications, inconsistencies, follies, and triumphs, and that whoever tries to grasp the age and make sense out of it is per se a crackpot. It is true — too true — that brand-new problems face us, that revaluations aplenty are in store. Surely the war and its aftermath are providing a break, a shake-up, the beginning of something new. Knowledge and understanding must be the foundation, and the thirst for knowledge and understanding does exist. To teach and to guide are functions of the museum. Hence, in its own sphere of action, the contributions that the museum can make, capitalizing on its experience in exhibition techniques and in democratization, will be of definite importance.

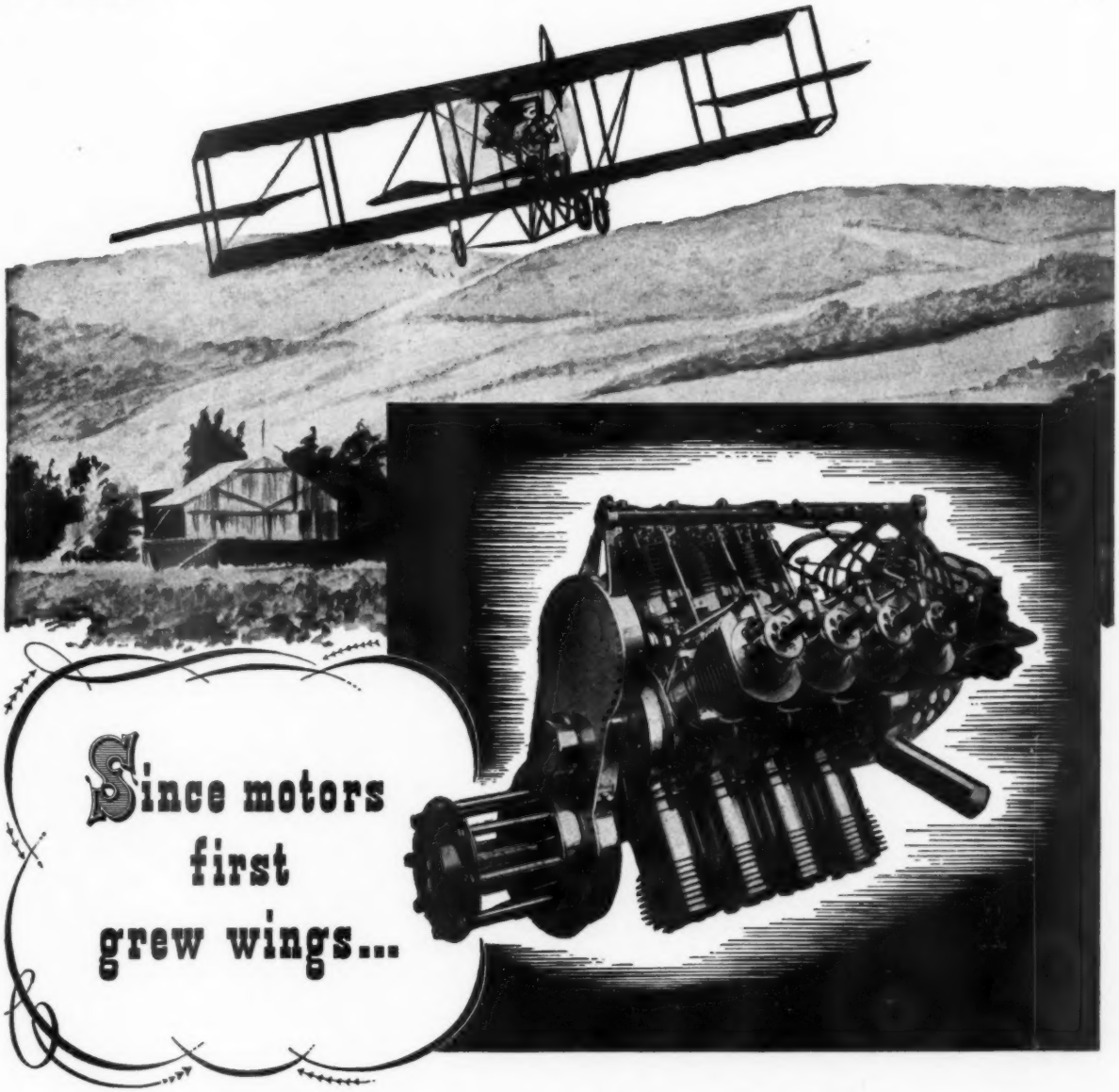
THE TREND OF AFFAIRS

(*Continued from page 480*)

journalists of today, chafing at the impracticability of reporting lesser matters, will suspect that Mr. Kelly's thoroughness in reciting the sad tale was a pleasant expiation of the fact that concerning the journalistic standoffishness of 1903 he can say a rueful "quorum pars fui." And there is, of course, some consolation to newsmen in the fact that the Army itself was none too alive to what had happened at Kitty Hawk.

The other more notable quality of Mr. Kelly's narrative is implicit: his comprehension and clear constant suggestion of the attitude of the Wright brothers toward each other, toward their work, and toward the world. These brothers who could argue long hours about the theory of their undertaking, until each had argued himself into the other's original position, constituted a research team in the best sense of the words. Their mutual

(*Concluded on page 512*)



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THE TREND OF AFFAIRS

(*Concluded from page 510*)

respect and self-respect, as Mr. Kelly presents them, were matched by respect for the materials, both physical and intellectual, with which they had to deal. This latter characteristic appears sharply in the singleness of purpose with which they worked upon the problem of flight during their available time and in the equally direct readiness with which they turned away from it to resume the earning of a living to make possible a resumption of the project. Through shrewd selection and straightforward presentation of detail, Mr. Kelly gives interesting insight into the personality of the two central figures in the drama.

Questions remain, however. Even in an age of such speed as our own, time must pass for perspective to be gained and for the full mass of detail to be straightened out and classified. *The Wright Brothers* is to be regarded as an able assistant to the historian in time to come. For the reader in the present, it is a friendly and informative way of coming to know two unassuming men who did a great thing.

Biotin

PERHAPS all plants and animals are ultimately made out of the same kind of mud. In any event, it is biologically interesting that a growth-stimulating factor for yeast (biotin), a growth and respiration factor in root-nodule bacteria of legumes (coenzyme R), and an antidermatitis factor in rats, chicks, and other animals (vitamin H) should all prove to be one and the same thing. We now call them all "biotin," and thanks to a considerable number of investigators in various laboratories the structure of the substance is quite completely known. Even more recently it has been entirely synthesized.

It is perhaps not unfair to consider that the synthesis of a substance like biotin has at the moment a largely academic significance. Biotin is a very remarkable vitamin in that it is one of the few essential nutritional substances which are not obtained primarily from food or apparently synthesized by man. In spite of this fact, under any ordinary conditions we have plenty of biotin to waste. We eject three to six times as much biotin as we get in our food. Indeed, determination of the nutritional significance of biotin has been a matter of some difficulty because the substance is so readily obtained by the body from the vast number of bacteria which we have always by us in the lower intestine.

Experiments on the significance of biotin to the human being have shown, for one thing, that a deficiency of biotin in children gives symptoms of dermatitis resembling those found in rats under similar conditions, while in adults the lack of biotin has been found to produce a fine, scaly dermatitis which disappears spontaneously after a time and is later succeeded by a gray pallor. These symptoms are accompanied by depression and lassitude as noticed in thiamine deficiency.

In their amounts of biotin, the tissues of embryos have been found to differ from the same tissues in the adult. This fact has led to an investigation which quite recently has shown that, in their biotin content, tumors and embryonic tissues deviate in the same direction from the adult. This result is a comfort to those who hold tumors to be the result of the activities of cells that have retained many of their embryonic properties.

The synthetic biotin which has lately been obtained has been shown, not only by physical and chemical tests but by biological tests as well, to be equivalent to the natural material and, as far as can be told, identical with it. The full detail of the preparation of the synthetic substance has not yet been published, and the real significance of the synthesis is not that it will enable us to obtain our biotin in pill form but rather that it proves the chemical structure which had been derived for biotin from an analysis of the natural material.

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Appointments

SINCE the announcement of the annual Faculty changes in May, three additional members of the staff have been promoted to the grade of assistant professor. They are John W. Irvine, Jr., '39, Department of Chemistry; William C. Bauer, '41, director, Parlin station, and James D. McNitt, '41, director, Bangor station, School of Chemical Engineering Practice.

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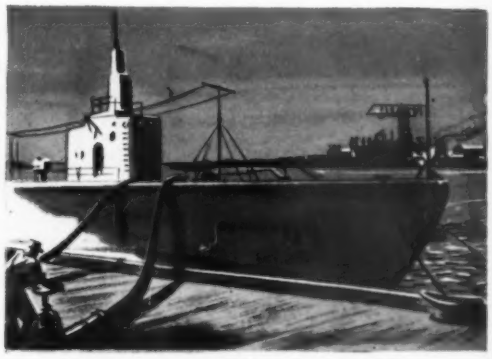

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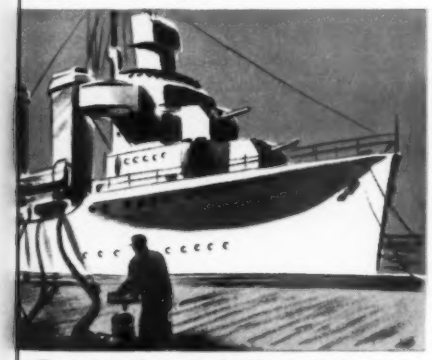

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